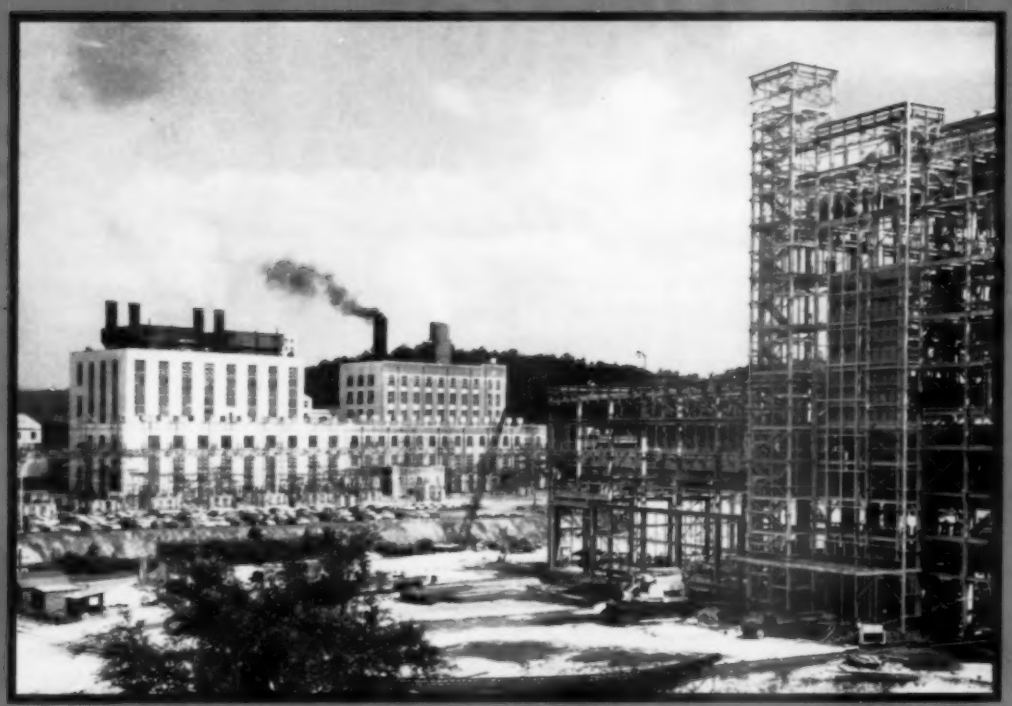
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

March 1956



Alabama Power Co.'s Gorgas Steam Plant No. 2, left, with Plant No. 3, right, under construction

Use of Suction Pyrometers In P. F. Furnaces

AIEE Winter General Meeting

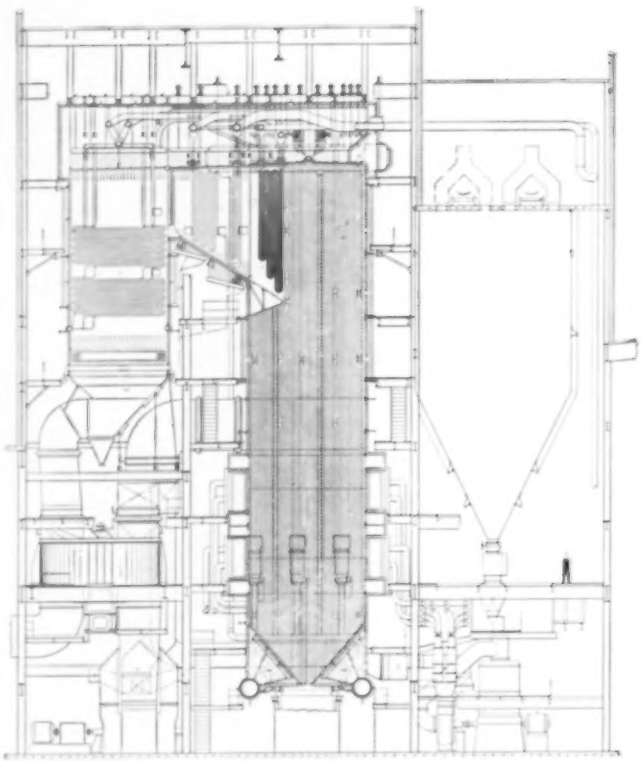
Corrosion and Deposit Control

Importance of Fuel Research

DEAN H. MITCHELL STATION

Northern Indiana Public Service Co.

C-E controlled circulation boilers



The C-E Unit shown above is presently under construction for the Dean H. Mitchell Station of the Northern Indiana Public Service Company at Gary, Indiana. Sargent and Lundy, Inc., are the consulting engineers.

This boiler is designed to serve a 125,000 kw turbine-generator operating at a throttle pressure of 1800 psig with a primary steam temperature of 1005 F, reheated to 1005 F.

It is of the controlled-circulation, radiant reheat type with a divided furnace arrangement. The reheater section is located between the primary and secondary superheater surfaces and an economizer section is located below the rear superheater surface. Regenerative type air heaters follow the economizer surface.

Pulverized coal firing is employed using bowl mills and tilting, tangential burners. Natural gas will also be used and arrangements are made for future use of oil if desired.

B-897

COMBUSTION ENGINEERING, INC.

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

STEAM GENERATING UNITS; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; DOMESTIC WATER HEATERS; SOIL PIPE

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 9**

March 1956

Feature Articles

The Use of the Suction Pyrometer in Pulverized-Fuel-Fired Furnaces ..... *By A. M. Godridge and G. G. Thurlow* 34

Diversified Program at AIEE Winter General Meeting 43

It Takes More Than Fire and Water to Make Steam ..... *By Gregory Gould* 49

Corrosion and Deposit Control in Cooling Water Systems ..... *By Cramer H. Cook* 53

The Importance of Fuel Research ..... *By Eugene Ayres* 57

Highlights of Nuclear Engineering and Science Congress—III 61

Editorials

An Undersold Asset 33

The British Electrical Generation Picture 33

Departments

Book Reviews 65

Advertising Index 82, 83

COMBUSTION published its annual index in the June issue and is indexed regularly by Engineering Index, Inc.

The magazine is now reproduced and distributed to libraries on microfilm by University Microfilms of Ann Arbor, Michigan.

GERALD S. CARRICK
Business Manager

JOSEPH C. McCABE
Editor

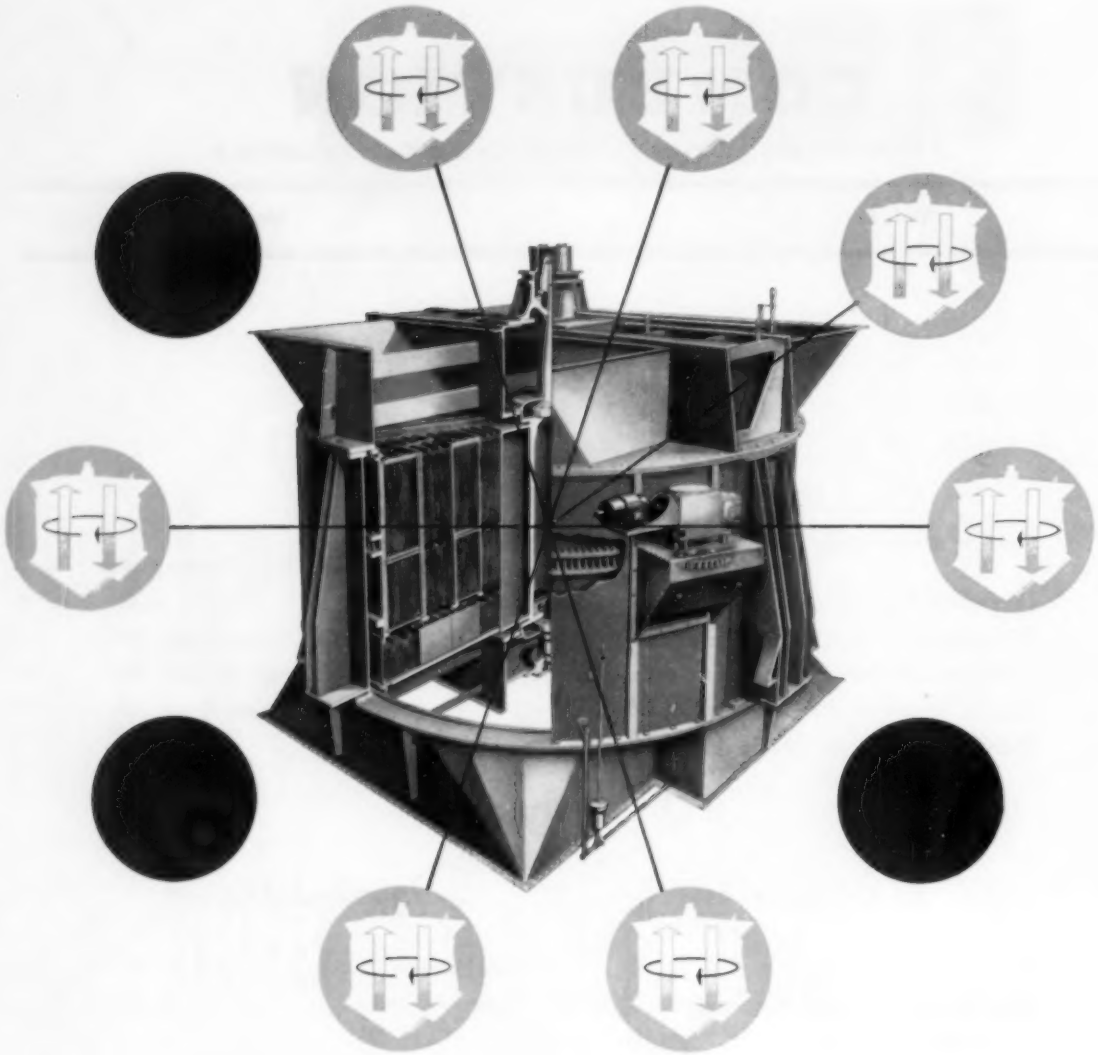
GLENN R. FRYLING
Associate Editor

CARL G. UDELL
Circulation Manager

Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Irving B. Swigart, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada; and $8 in Latin America and other countries. Single copies: Domestic, 40 cents: Foreign, 60 cents plus postage. Copyright 1956 by Combustion Publishing Company, Inc. Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P.L. & R., authorized by United States Post Office.

BPA

Printed in U. S. A.



7 out of 10 *air preheater installations are Ljungstrom®*

Advantages of the Ljungstrom Air Preheater

- Size for size, recovers more heat than any other type.
- Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.
- Eliminates cold spots . . . keeps corrosion to a minimum.
- Easier, faster to clean and maintain.
- Requires far less supporting steel and is quickly erected.

FUEL ECONOMY is the big reason. Size for size, the Ljungstrom recovers more heat than any other type of air preheater. And with every 45-50 F of air preheat you cut your fuel bill 1%.

Write now for your copy of our 38-page manual, for handy reference.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

47 miles of Johns-Manville 85% Magnesia Insulation boosts operating efficiency of Plant Hammond, one of the South's largest and most modern private utility installations.

Insulating feed water line at Plant Hammond. Contractor for this job was Brooks-Fisher Insulating Company of Atlanta, Georgia.

J-M 85% Magnesia Insulation helps cut fuel rate 25% below national average

Officials of the Georgia Power Company were gratified when the coal rate of their new Plant Hammond worked out at 0.75 lb. per KW HR, 25% below the national average. In their annual *Electrical Industry Statistics, Electrical World* had reported that increased efficiency in the techniques of power production has lowered the average coal rate to 1 lb. per KW HR. in 1954.

An important factor contributing to Plant Hammond's high efficiency was the selection of insulation. Johns-Manville's 85% Magnesia was applied in the most economical thicknesses throughout the plant for all piping and equipment operating in its temperature range. At higher temperatures 85% Magnesia was used in combination with J-M Superex® diatomaceous silica insulation.

This is only one of thousands of case histories where J-M 85% Magnesia has helped industry achieve outstanding fuel savings and increased operating efficiency. In all types of manufacturing and processing plants it is the standard for temperatures to 600F . . . providing high insulating value, easy application, long life, initial low cost and minimum maintenance. Write today for further information on J-M 85% Magnesia and Johns-Manville's complete drawing-board-to-job-site insulation service. Address Johns-Manville, Box 60, New York 16, New York. In Canada, Port Credit, Ontario.

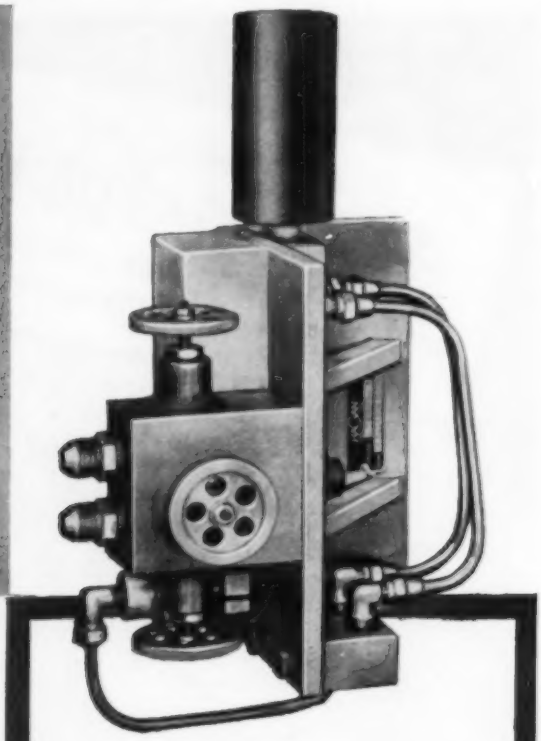
JM PRODUCTS

Johns-Manville *first-in* INSULATION

MATERIALS · ENGINEERING · APPLICATION

Accurate, measurement of pressure differentials up to 300 psi

HAGAN DELTA 'P' PRESSURE TRANSMITTER



The Hagan Delta 'P' Transmitter is a sturdy, compact, force-balance instrument for pneumatically transmitting large pressure difference measurements. Consider these features:

1. No stuffing boxes, torque tubes or pressure-tight bearings.
2. Not affected by static pressure changes.
3. Usable at any static pressures up to 3000 psig.
4. Full scale pressure difference measuring ranges from 50 psi to 300 psi with 1% full scale accuracy.
5. Shut-off and by-pass valves integral with instrument.
6. Not damaged by accidental application of full line pressure to either side of measuring element.
7. Stainless steel pressure elements, cadmium-plated steel frame.
8. Shock and vibration proof design.

A few Applications of the Delta 'P' Transmitter

Pneumatic signals from the transmitter are in the range of 0-30 psig, and may be used for indications and records, or for control of factors involved in such functions as:

Pressure difference between steam and boiler feedwater headers.

Steam pressure drop across superheater.

Pressure drop between boiler outlet and turbine throttle.

Pressure drop across high pressure heat exchangers.

Measuring pressure drop across liquid flow control valves for graduated control of pump discharge presssure.

As a "square root" flow meter when pressure differentials are higher than conventional flow meter design.

Measuring pressure differentials for alarm signal purposes under critical operating conditions, such as seal gas pressure during repair periods in a catalytic reformer unit.

HAGAN CORPORATION

HAGAN BUILDING, PITTSBURGH 30, PA.

HAGAN

Systems and Components for: Boiler Combustion Control, Metallurgical Furnace Control, Process Control, Aeronautical Testing Facilities • Industrial Water Treatment • Chemicals for Water Conditioning

HAGAN SUBSIDIARIES: CALGON, INC. • HALL LABORATORIES, INC.

Nothing like a symphony orchestra under a competent director . . . or, in industrial construction, a general contractor integrating the individual skills of many trades. Yet, the fabricating and erecting of high-temperature and high-pressure piping is a job only for a soloist—a soloist of highly-specialized talent.

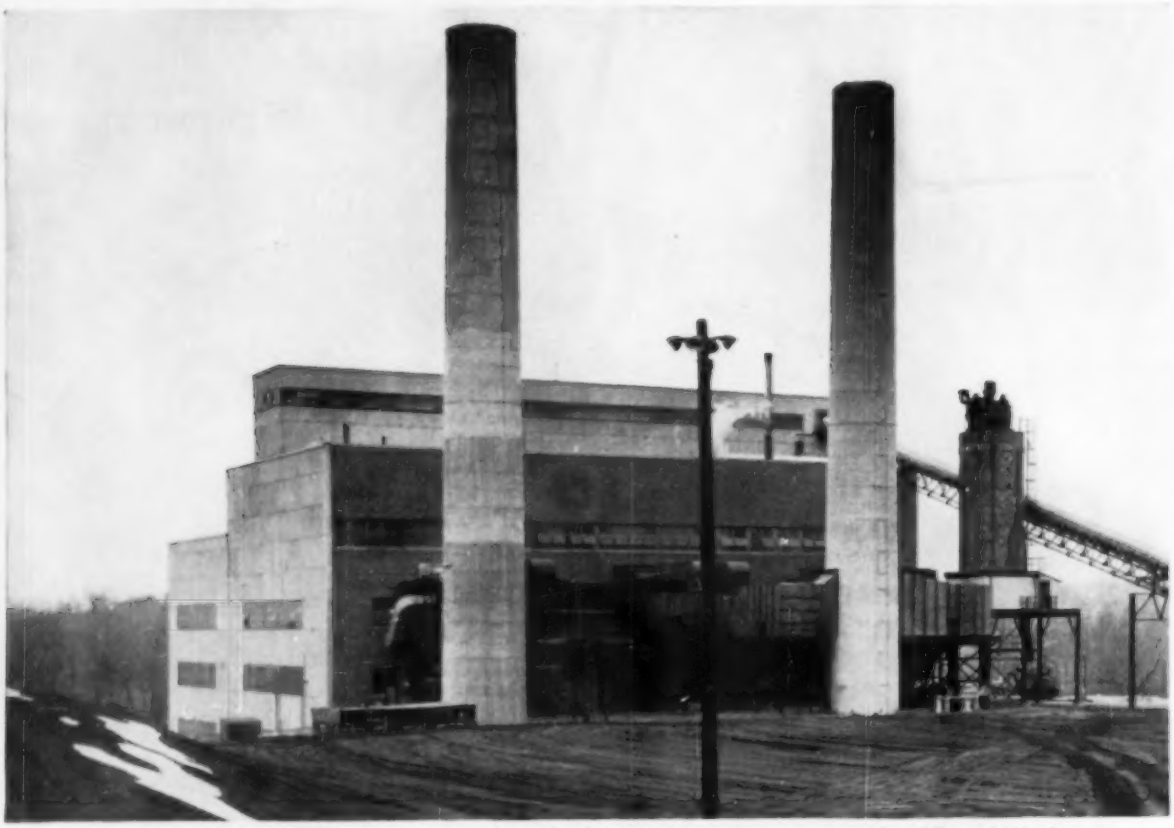
Ask us in—to collaborate with *your* engineers.

W. K. MITCHELL & CO., INC.
Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

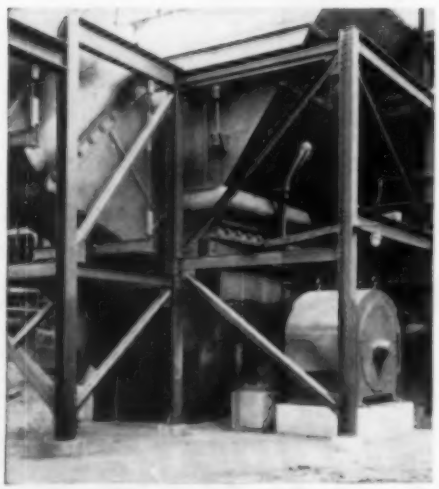
MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS



Sabrooke Station's third generating unit adds 30,000 kw: raises system capacity of Central Illinois

Demand tops 100,000 kw mark



American Blower Sirocco Induced Draft Fan at Sabrooke Station is rated at 184,000 cfm @ 340° F @ 14.5" sp @ 600 hp. American Blower Draft Fans are also installed at company's Fordam Station.

Central Illinois Electric and Gas Co. puts new generating unit on the line to meet area needs; relies on American Blower Mechanical Draft Fans.

Shortly after the third steam-generating unit began operation in October 1955 at Sabrooke Station, the Central Illinois Electric and Gas Co. marked a milestone. *For the first time in the company's history*, the electrical needs of its Rockford service area exceeded 100,000 kw!

Indeed an important event, the new unit demonstrates this growing company's ability to more than meet the demands of the future . . . a future in which American Blower equipment has an important role.

Like the Central Illinois Electric and Gas Co., many other progressive, investor-owned utilities have also decided on American Blower equipment. They know from past-performance records that American Blower products are reliable, and are built to meet rigid power-plant requirements.

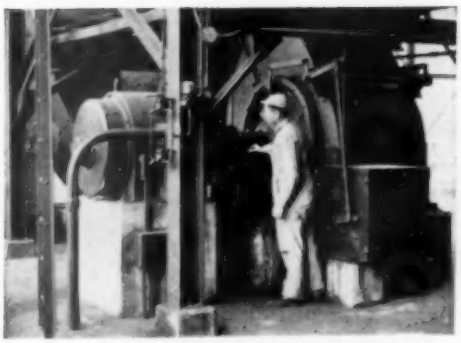
We'd be pleased to give *you* full facts on our Mechanical Draft Equipment, Fly Ash Precipitators, Heavy Duty Steam Coils, and Gyrol Fluid Drives for boiler feed-pump and fan control. Just give our nearby branch office a call.

American Blower

reports on progress in power

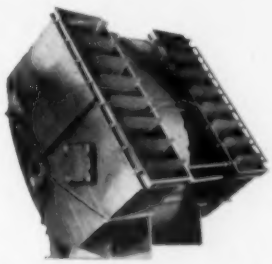
Electric and Gas Co. to 156,450 kw.

in Rockford, Ill.

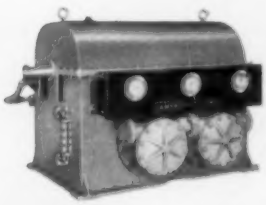


American Blower Forced Draft Fan has capacity of 104,000 cfm @ 90°F @ 9.5" sp @ 250 hp.

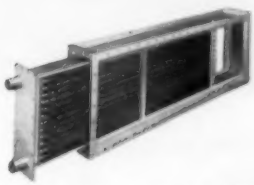
AMERICAN BLOWER PRODUCTS SERVE AMERICA'S POWER NEEDS



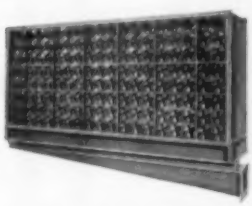
Mechanical Draft Fans for forced and induced draft.



Gyrol Fluid Drives for boiler feed-pump and fan control.



Heavy duty steam coils for high-pressure duty.



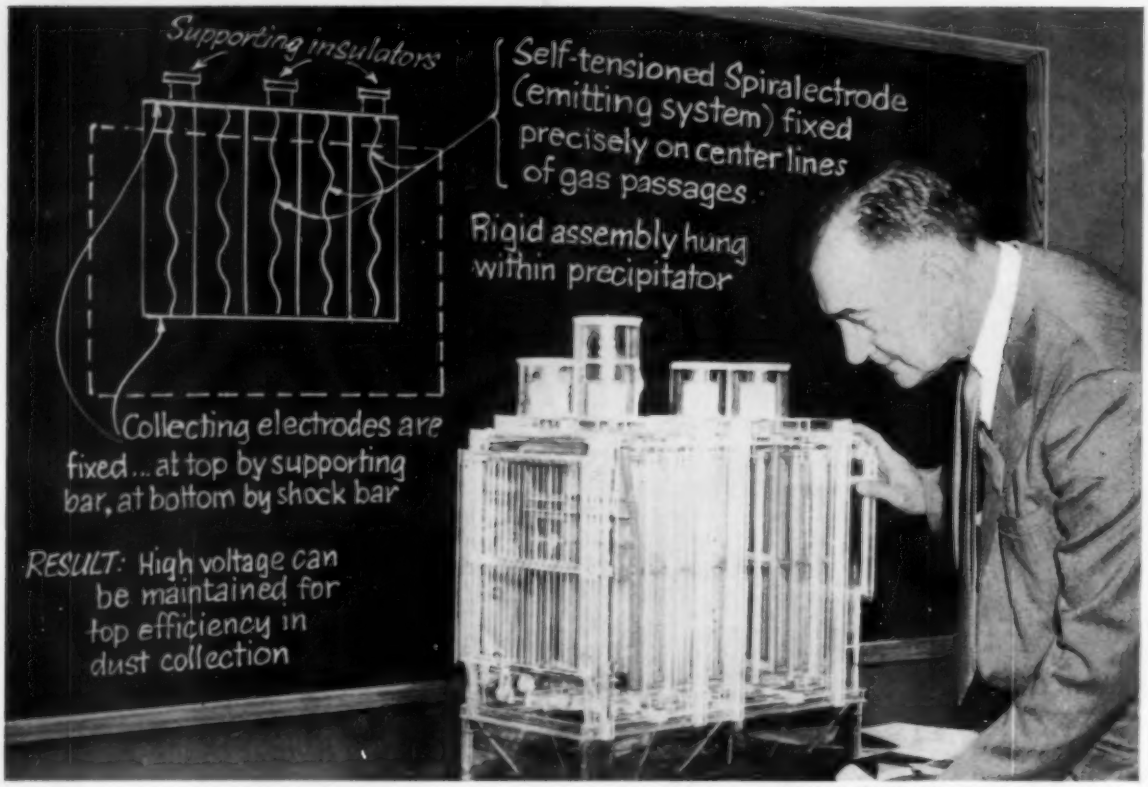
Collectors and precipitators for dust and fly ash control.

AMERICAN BLOWER CORPORATION, DETROIT 32, MICH. • CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

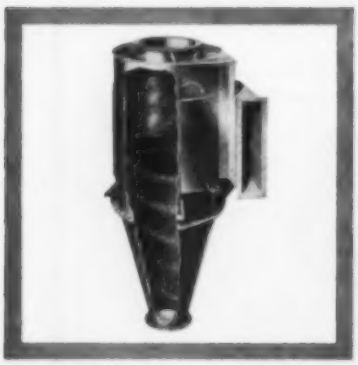
Division of American-Standard

AMERICAN 75th ANNIVERSARY YEAR BLOWER

How fixed electrodes assure top efficiency in a Buell "SF" Precipitator

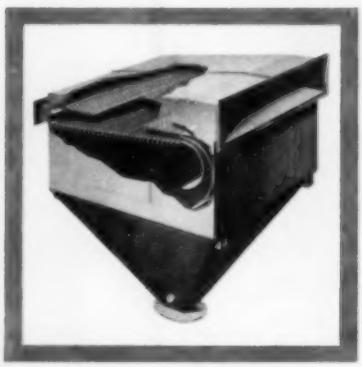

Supporting insulators
Self-tensioned Spiralectrode (emitting system) fixed precisely on center lines of gas passages
Rigid assembly hung within precipitator
Collecting electrodes are fixed... at top by supporting bar, at bottom by shock bar
RESULT: High voltage can be maintained for top efficiency in dust collection

PHOTOGRAPH OF BUELL PLASTIC MODEL BY INDUSTRY & POWER



Buell Cyclones also assure top efficiency with large diameter design to eliminate clogging . . . and by harnessing double-eddy and putting it to work.

Even when high-resistivity dusts must be collected, top efficiency is guaranteed by the exclusive shape of Buell's Spiralectrodes—proved to give 50-100% greater emission than straight wires. Exclusive Continuous Cycle Rapping virtually eliminates maintenance by keeping electrodes constantly clean.



Buell's Low Resistance Fly Ash Collector combines top efficiency to meet present strictness, with low draft loss for natural or mechanical installations.

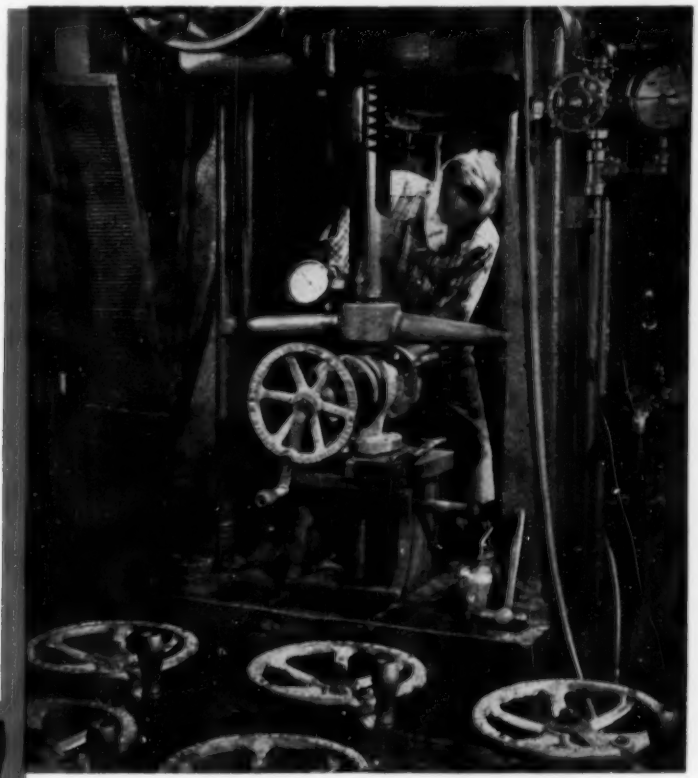
GET ALL THE FACTS

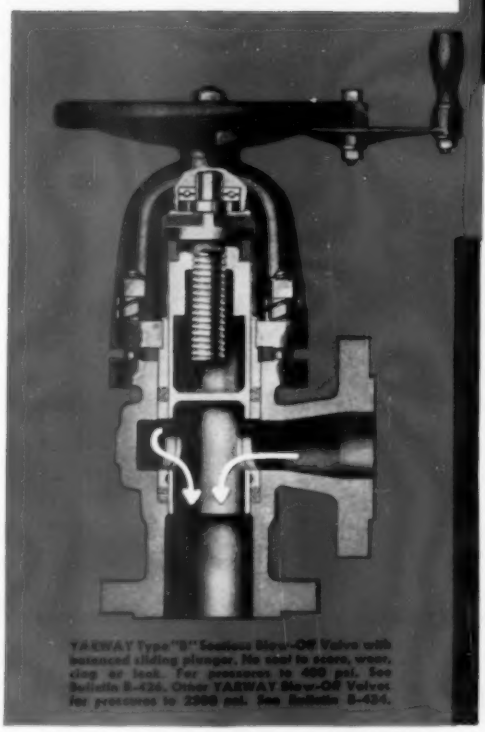
Write to:
Buell Engineering Company,
Dept. 70-C, 70 Pine Street,
New York 5, New York

buell®

MECHANICAL ELECTRICAL

Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**





YARWAY Type "B" Seamless Blow-Off Valve with balanced sliding plunger. No seat to score, wear, clog or leak. For pressures to 400 psi. See Bulletin B-426. Other YARWAY Blow-Off Valves for pressures to 2500 psi. See Bulletin B-434.

THIS PRODUCTION "DOUBLE CHECK" SAFEGUARDS YOUR BOILER INVESTMENT!

■ Yes, here is one extra production step we will never bypass! It is your guarantee of a *dependable*, long-life blow-off valve.

In this corner of the YARWAY Testing Department, *every Yarway Blow-Off Valve* is hydrostatically tested at 1½ times its rated maximum working pressure—proved drop-tight for service far beyond normal expectancy.

Not only blow-off valves, but *all* YARWAY equipment undergoes rigorous tests before leaving the YARWAY plant. Why? For one reason—to assure longer and better service in *your* plant. Over 15,000 boiler plants are using YARWAY Blow-Off Valves—some for twenty-thirty years, or longer.

Whenever you are in need of boiler blow-off valves, be sure to *make Yarway your way.*

YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY

steam plant equipment

BLOW-OFF VALVES
WATER COLUMNS AND GAGES
REMOTE LIQUID LEVEL INDICATORS
EXPANSION JOINTS
DIGESTER VALVES
STEAM TRAPS
STRAINERS
SPRAY NOZZLES

NOW!

"BUFFALO"

VARIABLE INLET DRAFT CONTROL

—WITH FIXED VANE PERFORMANCE AT WIDE OPEN POSITION

The variable inlet vanes of this "Buffalo" Forced Draft Fan are cantilevered into the fan's inlet shroud, with the operating linkage behind the shroud and entirely out of the air stream. This provides clear and unobstructed air flow. Further, the variable vanes are curved to the same degree as the well-known "Buffalo" fixed vanes, for which the fan is designed. Because "Buffalo" Fans are designed for fixed vanes the use of variable vanes *results in less than one percent reduction in rated capacity.* Construction is accessible and trouble-free. The entire lever and control ring assembly is permanently aligned for smooth operation with no backlash.

Here is one more illustration of the "Q" Factor* of performance and satisfaction that is yours when you specify "Buffalo" for mechanical draft.

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

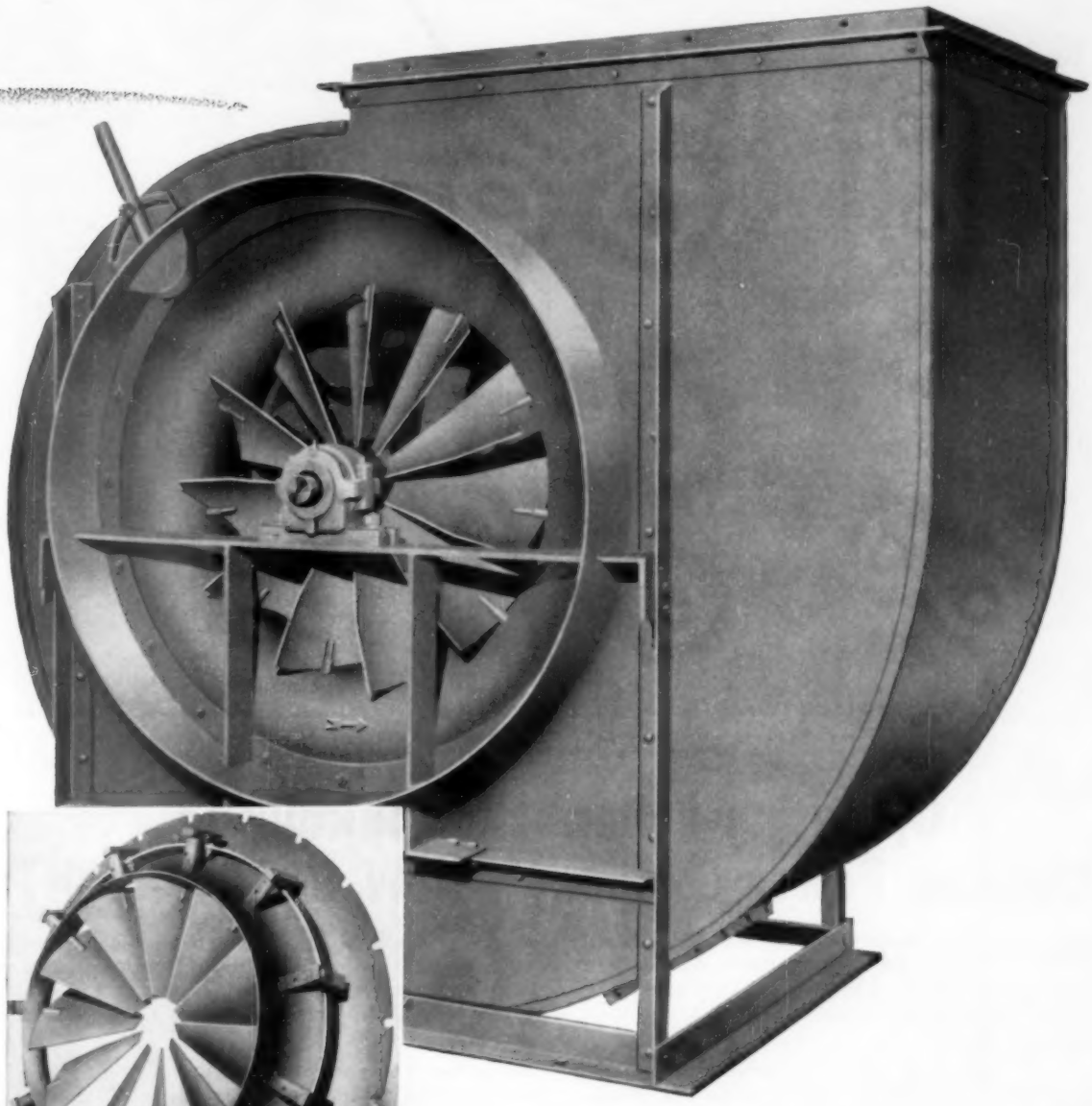
"Buffalo"

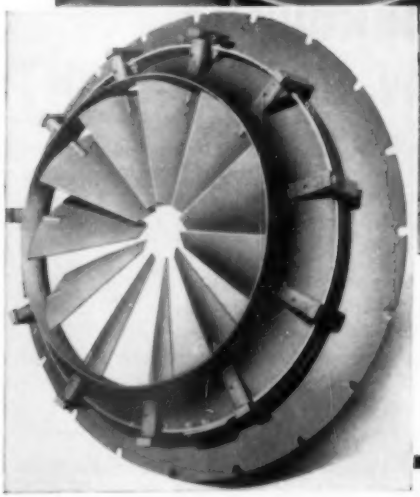
BUFFALO FORGE

BUFFALO,

Canadian Blower & Forge Co., Ltd.,

VENTILATING AIR CLEANING AIR TEMPERING PRESSURE BLOWING





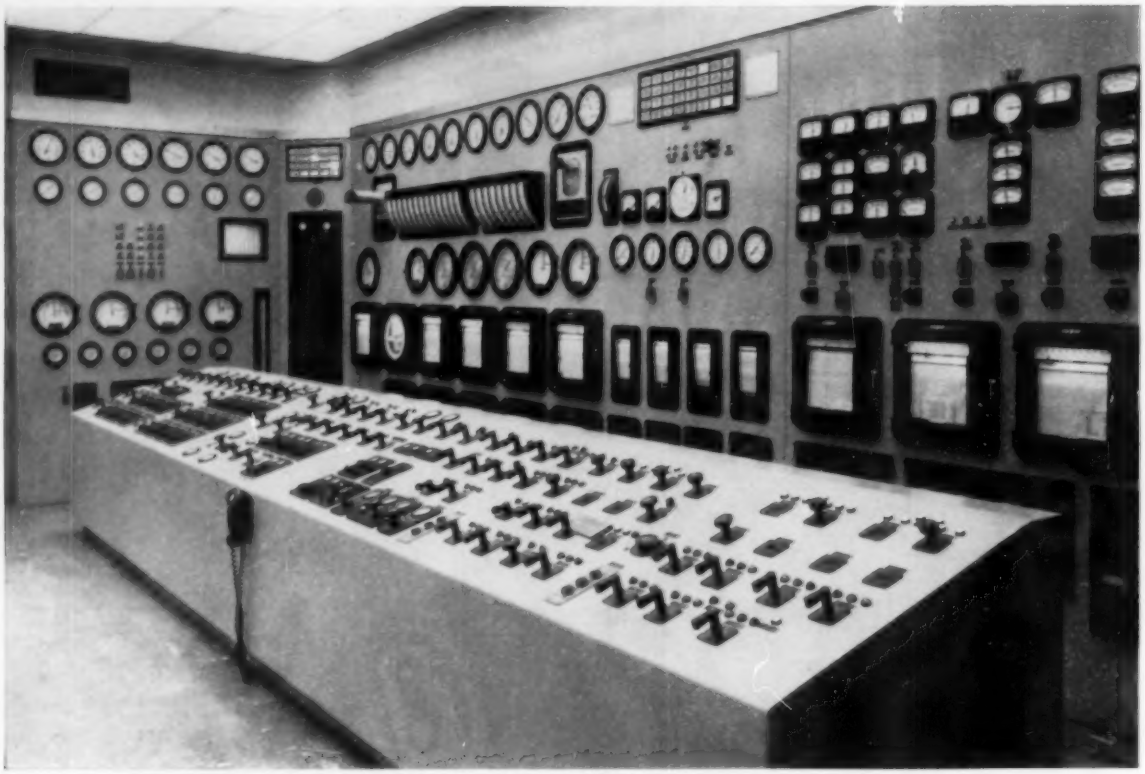
Note how cantilevered arrangement of "Buffalo" Variable Inlet Vanes permits unobstructed air flow. Write for Bulletin F-1510 for full details on this smooth draft control with high performance.

COMPANY

NEW YORK

Kitchener, Ontario

INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING



Centralized controls for station service switching, two 125,000 kw turbines, generators and boilers are in this room. Republic sub-panels on the bench board provide for either automatic or manual control of the boilers.

Operating Boilers Electronically at Alabama Power Company's NEW BARRY PLANT

At the new Barry Steam Plant near Mobile, Alabama, two 900,000 lbs. per hour pulverized coal fired boilers operating at 1875 psi and 1000°F. are controlled by a Republic Electronic Master Combustion Control System.

Electronic impulses control pneumatically operated fuel, draft, and feedwater regulators on the boilers. Master control signals are transmitted practically instantaneously, permitting fast control response and close boiler control.

To ensure that both final firing rate and air flow will rapidly and accurately follow changes in steam load, the control system normally follows a dual element master control. This master controls the boiler auxiliaries from a rapid and proportional steam flow function together with a stabilized steam pressure function. Such a system combines the features of derivative control with automatic correction for fuel variation in such a manner that the effects of load swings are minimized almost to the vanishing point. Other control problems such as feedwater control and steam temperature control are simplified by the coordination of boiler auxiliary functions due to this system of combustion control.

Boiler feedwater is controlled automatically by a Republic three-element feedwater control. To prevent heat damage to feedwater pumps during low flows, a Republic pump by-pass system has been installed. It automatically maintains a minimum flow of 125 gpm through each pump (two pumps per boiler) returning by-passed water to the deaerating heater storage tank.

Final efficiency tests recently completed at the Barry plant indicate the expected plant heat rate has been fully realized. There are Republic Automatic Combustion Control Systems — electronic or pneumatic — for all sizes and types of boilers, all methods of fuel firing and for any arrangement of draft equipment. For full details, write today.

REPUBLIC FLOW METERS CO.

2240 Diversey Parkway, Chicago 47, Illinois

TAXE$ . . . earned by brick

If you own securities . . . if you're paid a salary . . . if you earn commissions . . . no matter how you make your income, the starting point is brick. Refractory brick.

Refractories, the industry behind industry. Refractories that contain and control flame . . . the flame that produces metals, glass, paper, rubber, oil, cement, power, transportation. Everything that's made or moved requires them.

But those requirements vary . . . vary over a vast range of applications. To provide them in almost infinite variety and enormous quantity, Grefco employs extensive research, maintains the world's most modern refractories laboratory, and supplies a Complete Refractories Service from strategically located plants, both here and abroad, that draw on the world for materials.

A Complete Refractories Service
GENERAL REFRACTORIES COMPANY
Philadelphia 2

SEND FOR THE MOTION PICTURE: THE GREFCO STORY

It is a beautiful 16 mm. motion picture in full color and sound which relates the fascinating and little understood story about the refractories industry... *the industry behind industry*. Viewing time is 26 minutes. If you would like to show it to executive, employee, social, church or other groups, a request on your letterhead is all that is necessary. Address General Refractories, Philadelphia 2.

GENERAL REFRACTORIES

UNCERTAIN OPERATING COSTS BOTHER YOU?

depend on the only

long range economy fuel

You'll win in the long run by burning Bituminous! Today and tomorrow, supply is unlimited and the vast reserves are right on the threshold of the major manufacturing centers. Bituminous, too, has the highest potential for cost improvement among competing industrial fuels. Year in and year out new methods and machines are designed to control costs and improve burning efficiency.

Let B&O's Technical Service fit this fuel to your long range power plans.
Ask our man!

COAL TRAFFIC DEPARTMENT
BALTIMORE & OHIO RAILROAD
Baltimore 1, Maryland
Phone: LExington 9-0400

BALTIMORE & OHIO RAILROAD

BITUMINOUS COALS FOR EVERY PURPOSE

FLUID COKE: *Development in Petroleum*

Refining Produces Valuable New Fuel

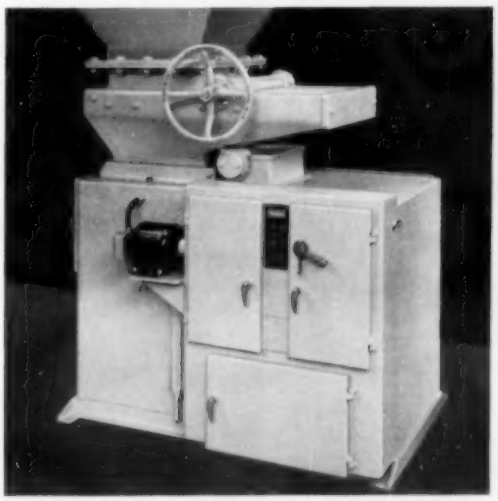
A relative newcomer to the power field, fluid coke seems destined to attain prominence in a short time. Although used in the charge of a by-product coking oven, and for various metallurgical processes, etc., fluid coke will find its principal use as a combustion material.

What is fluid coke? Fluid coke is a product of a new refining process developed and patented by the Esso Research and Engineering Company, a process which produces a high yield of gas-oil, which can be cracked to high octane gas, and a relatively low yield of coke. The coke itself differs greatly from regular petroleum coke. Particles are small, like fine sand. The particles pour freely, and are clean in comparison with other coke. Fluid coke burns with a minimum of ash. Even allowing for an extra high ratio of unburned carbon, up to 20%, heat output is comparable to that of coal of about 14,000 B.t.u./lb. Auxiliary fuel such as oil or high volatile coal must be used to bring coke up to ignition temperature and maintain a regular flame.

How much fluid coke is being produced? Present capacity of refineries is only 350 tons per day. However, total capacity of all plants now in the building or planning stage will run about 2,500 tons per day, or about ¼ of the production of petroleum coke in this country. All companies are producing the coke under license from Esso.

Who is using fluid coke? First boiler installation designed to use fluid coke as a primary fuel will be the Delaware Power & Light Company plant at Delaware City, Delaware. Coke will come from the refinery built by Tide Water Associated Oil Company. Another eastern utility has provided an outlet for the production of Esso's Baltimore refinery. Other utilities and industrial power installations will follow suit as production of the coke increases.

A small free sample of the fluid coke is available — simply write to the address listed below.



Plants which will use fluid coke as commercial fuel include the new Delaware City Power Station of Delaware Power & Light Company. This plant will serve the new Tide Water Associated Delaware Flying —A— Refinery now under construction 15 miles south of Wilmington with C. F. Braun & Co. as engineers and contractors. Stock Equipment Company is proud to announce that specially-designed S-E-Co. Valves and Scales, like the ones pictured above, will be used to weigh coke as it goes to the pulverizers.

SPECIALISTS IN
BUNKER TO PULVERIZER AND
BUNKER TO STOKER EQUIPMENT

STOCK Equipment Company

745-C HANNA BLDG., CLEVELAND 15, OHIO

Today's

C-E STANDARD BOILERS

bring new standards of economy and reliability

If you need steam from 4,000 to 120,000 pounds per hour—or high-temperature water for heating or process applications—one of these versatile C-E Boilers will give you economical, standout performance.

Collectively, they offer you an exceptional diversity of choice. A brief consideration of the features of each will help you "pin-point" the design characteristics best suited to your situation. And remember: While they are standard in design *(which means lower first cost and proven performance)*, they are still *flexible* enough to be easily adapted to your exact requirements.

Of course, Combustion Boilers are available in other 2-drum designs . . . for capacities up to 350,000 lb of steam per hr . . . for pressures to 1375 psig . . . for temperatures to 960 F. . . . for any fuel or method of firing.

Please feel free to call upon us for further detailed information. Catalogs of each of the units shown here are available upon request.

C-E

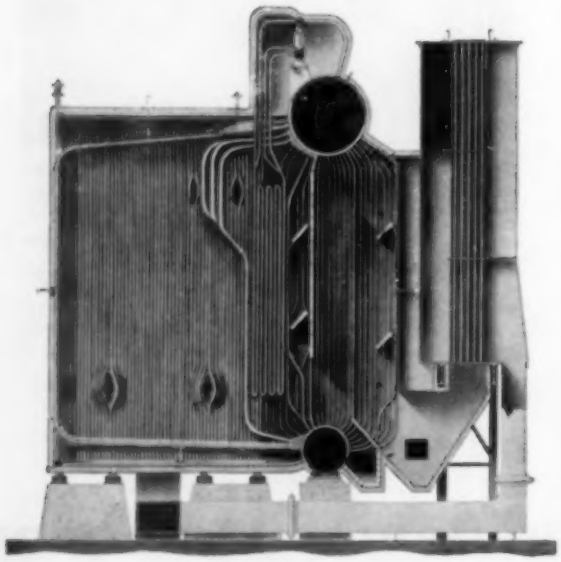
B-862

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

Canada—Combustion Engineering-Superheater, Ltd., Montreal

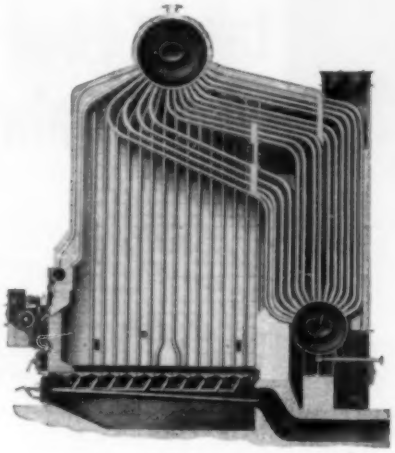
STEAM GENERATING UNITS; NUCLEAR REACTORS; PULVERIZERS, AIR SEPARATORS & FLASH DRYING SYSTEMS; PRESSURE VESSELS; AUTOMATIC WATER HEATERS; SOIL PIPE



C-E Vertical-Unit Boiler, Type VU-55

Capacity—from 50,000 to 120,000 lb of steam per hr.

The VU-55 Boiler is available in six sizes and is designed for two pressure ranges—up to 250 psig and to 500 psig. These units are arranged for the application of superheater surface and heat recovery equipment if desired. VU-55 Boilers are designed for the pressure firing of oil or gaseous fuel and require no induced draft fan. They are equipped with tangential burners and tangent tube furnace walls to assure a level of performance which compares favorably with modern utility practice. The VU-55 Boiler is bottom supported, requiring no supporting steel structure. The absence of exterior ductwork permits a smooth, streamlined exterior which is both attractive and practical.



C-E Vertical-Unit Boiler, Type VU-10

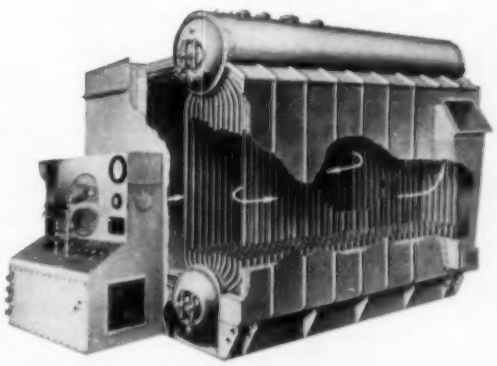
Capacity—from 10,000 to 60,000 lb of steam per hr.

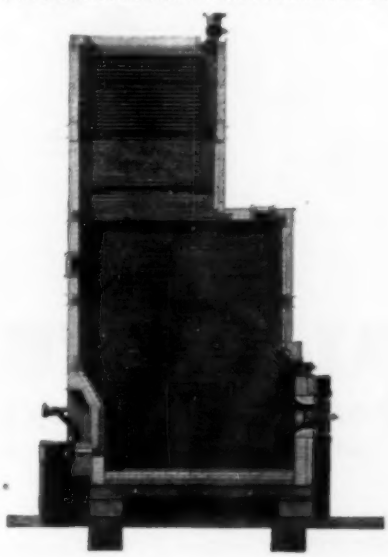
The VU-10 is available in nine sizes . . . for operating pressures up to 475 psi . . . superheat to 200 F in 20,000-60,000 lb range . . . for solid, liquid, or gaseous fuels. This boiler is a completely standardized design adaptable to many conditions. It is bottom-supported and needs no outside supporting steel. It operates efficiently over a wide range of output, and is easy to operate and to maintain. All parts are easily accessible for inspection. The VU-10 is a complete unit — boiler, furnace, setting, fuel-burning equipment, controls, forced draft, heat recovery equipment (if desired). Regardless of fuel, the same general cross-sectional arrangements of drums, convection bank and furnace wall cooling is used. Uniform design through each transverse section assures even water level in the drum and uniform expansion.

C-E Package Boiler, Type VP

Capacity—from 4,000 to 40,000 lb of steam per hr.

This completely shop-assembled boiler is available in fourteen sizes . . . for operating pressures up to 500 psi . . . for pressure firing of liquid or gaseous fuels. The VP Boiler has more water-cooled area per cubic foot of furnace volume than any other boiler of its size and type. The large lower drum — 30-inch diameter — permits a simple, symmetrical tube arrangement . . . greater water storage capacity . . . easy access for washing down or inspection. A low speed centrifugal fan which is exceptionally quiet in operation is standard equipment. The simple baffle arrangement results in low draft loss . . . simple soot blowing . . . no dead pockets . . . high heat absorption. The VP is enclosed in a reinforced, gas-tight, welded steel casing, and shipped completely assembled with firing equipment, fittings and forced draft fan. For foundation, it needs only a simple concrete slab.





The New C-E La Mont Controlled Circulation Hot Water Boiler

Capacities up to 200,000,000 Btu per hr.

For those applications where high temperature water has inherent advantages over steam—and there are many — the C-E La Mont HT Boiler has numerous points of superiority. Among the more important of these are:

1. **Complete control** over HT water movement in both system and boiler.
2. **Low pressure** loss is inherent so no separate boiler pump is required.
3. **Pressurized operation** with oil or gas means no induced draft fan — simple stack.
4. **Single-pass design** has no baffles—low draft loss—cleaner boiler.
5. **More efficient heating surface** can be arranged because of positive, controlled circulation.
6. **Other features** such as: steel enclosed setting — few headers, all accessible—any fuel, oil, gas or coal. For pressures to 300 psig and temperatures to about 425 F.

IDENTIFICATION DISC: An aluminum marking plate on all Walworth No. 225P's facilitates inventory control and makes reordering quick and positive.

take a good look at the Walworth "500 Brinell" no. 225P Globe

NEWLY DESIGNED HANDWHEEL: Patented air-cooled, finger-fit handwheel affords sure grip even with greasy gloves.

– the Toughest Bronze Valve Your Money Can Buy

The stainless steel, corrosion resistant seats and discs are heat treated to a hardness of 500 Brinell – hard enough to scratch glass and crush nails! The valve can be closed on sand, slag, and pipe scale without injury to the seating surfaces. "Wire drawing" is practically eliminated. All parts are accurately machined and gaged. Years of tight, positive shut-off are assured.

Available in both globe and angle types (angle type: No. **227P**) in sizes ¼" to 2", this quality valve is recommended for 350 lbs. W.S.P. at 550 F, and 1000 lbs. non-shock service on cold water, oil, gas, or air.

For full data on this long-life, economical Walworth Bronze Valve, see your local Walworth distributor, or write for Circular.

IMPROVED PACKING: Molded packing of lubricated asbestos reinforced with copper wire. Suitable for practically every service. Valves can be repacked under pressure when fully opened.

note these 7 Great Features

HEXAGONAL UNION BONNET CONNECTION: Union bonnet connection eliminates any chance of distortion or leakage even though valve is repeatedly taken apart and reassembled.

OVERSIZE STEM: The high-tensile strength silicon-bronze stem assures long life and protection against wear.

SEATS AND DISCS: Plug type seats and discs of stainless steel, heat-treated to 500 Brinell hardness and machined simultaneously to a mirror-like finish, with accurate tapers assures tight positive shut-off with minimum handwheel effort.

EXTRA STRONG BODY: Made of Composition M (ASTM B61) bronze. Thick walls and rugged hexes provide a high safety factor. Valves undergo hydrostatic shell test of 1,200 psi.

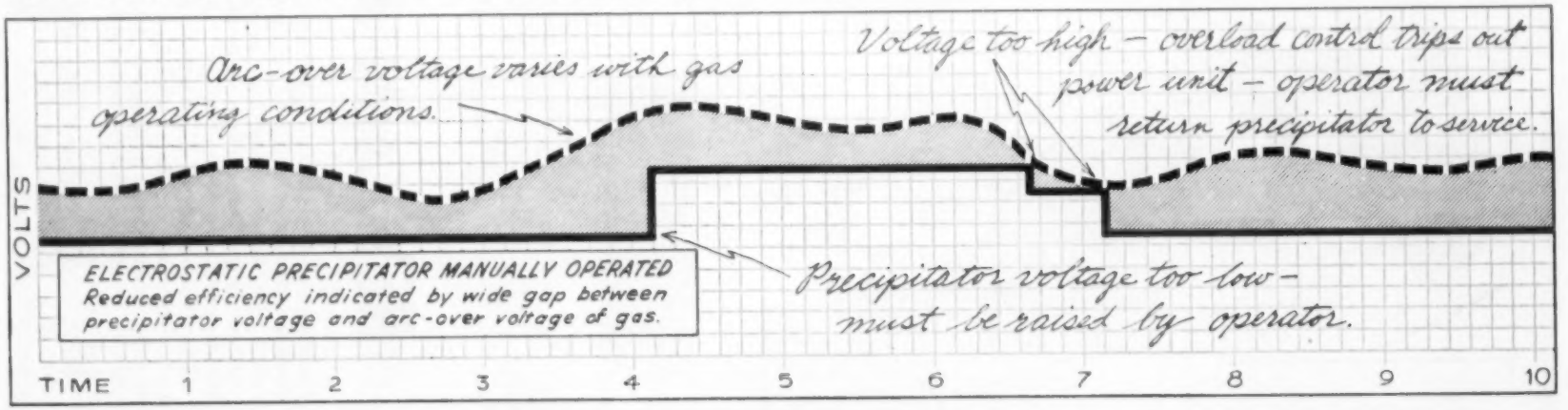
WALWORTH

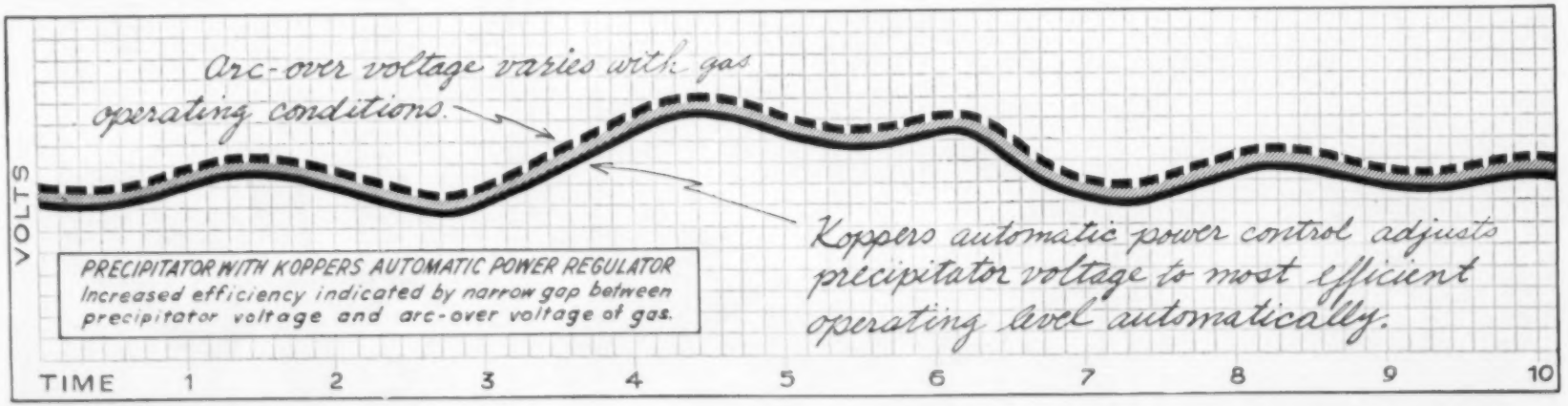
valves and fittings

60 EAST 42nd STREET, NEW YORK 17, N. Y.

DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

EFFICIENCY GRAPHS: Comparative graphs show the relative difference between MANUAL and AUTOMATIC power operation for electrostatic precipitators


Arc-over voltage varies with gas operating conditions.
Voltage too high – overload control trips out power unit – operator must return precipitator to service.
VOLTS
ELECTROSTATIC PRECIPITATOR MANUALLY OPERATED
Reduced efficiency indicated by wide gap between precipitator voltage and arc-over voltage of gas.
Precipitator voltage too low – must be raised by operator.
TIME 1 2 3 4 5 6 7 8 9 10


Arc-over voltage varies with gas operating conditions.
VOLTS
PRECIPITATOR WITH KOPPERS AUTOMATIC POWER REGULATOR
Increased efficiency indicated by narrow gap between precipitator voltage and arc-over voltage of gas.
Koppers automatic power control adjusts precipitator voltage to most efficient operating level automatically.
TIME 1 2 3 4 5 6 7 8 9 10

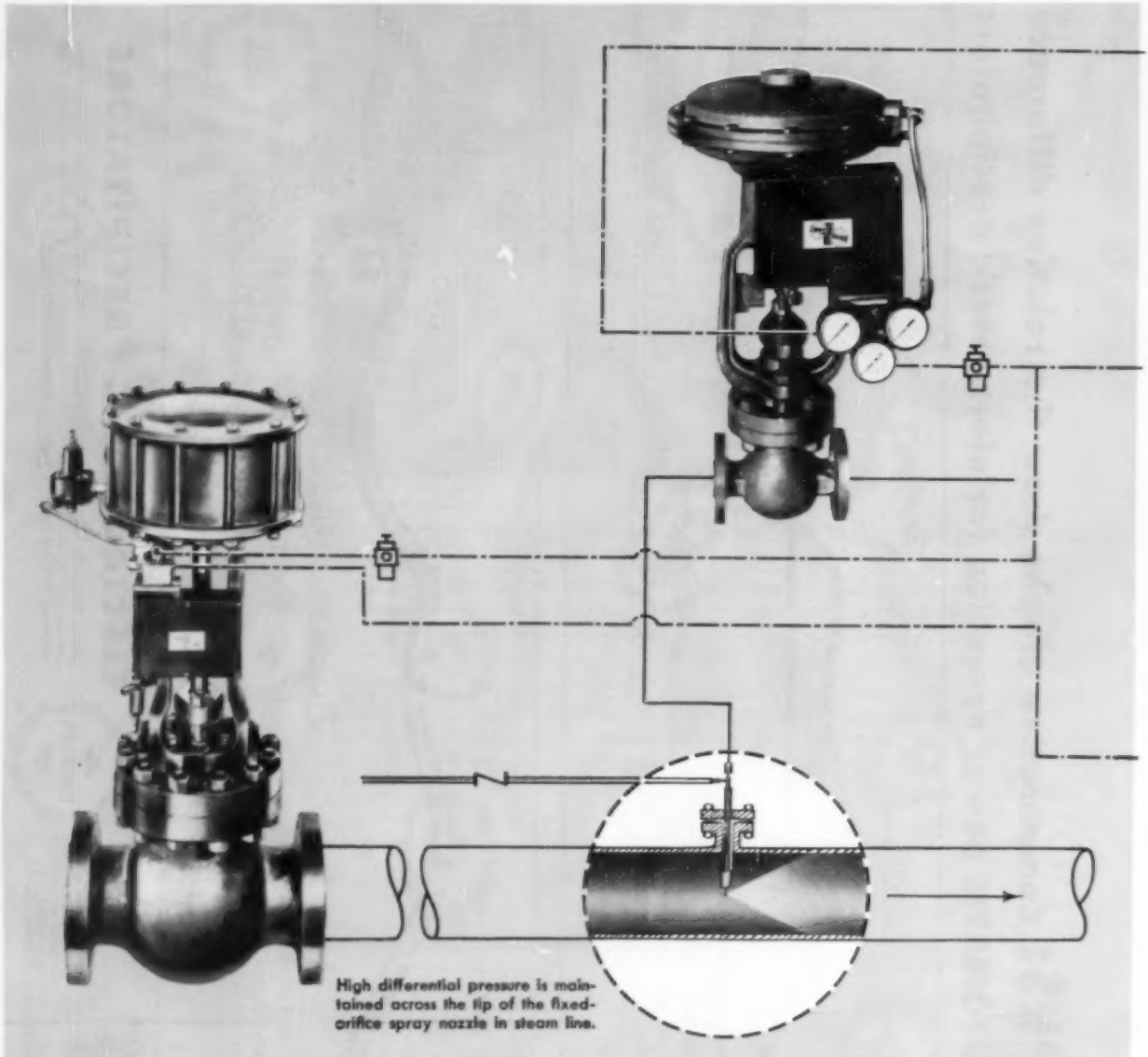
SEND FOR FREE BULLETIN

Free bulletin shows in detail how this compact cabinet unit reduces wasteful "sparkover" and enables Koppers Precipitators to operate continually at peak efficiency voltage without frequent "trip-outs." See how this new Koppers Automatic Power Regulator eliminates need for constant personal attention. For bulletin M40 . . . or if you desire an analysis, or recommendation for your operation . . . write to Koppers Company, Inc., *Industrial Gas Cleaning Dept.*, 4403 Scott St., Baltimore 3, Md.

KOPPERS

ELECTROSTATIC PRECIPITATORS

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • BALTIMORE 3, MD. This Koppers Division also supplies industry with Fast's Couplings, American Hammered Industrial Piston and Sealing Rings, Aeromaster Fans, Gas Apparatus. Engineered Products Sold with Service.



High differential pressure is maintained across the tip of the fixed-orifice spray nozzle in steam line.

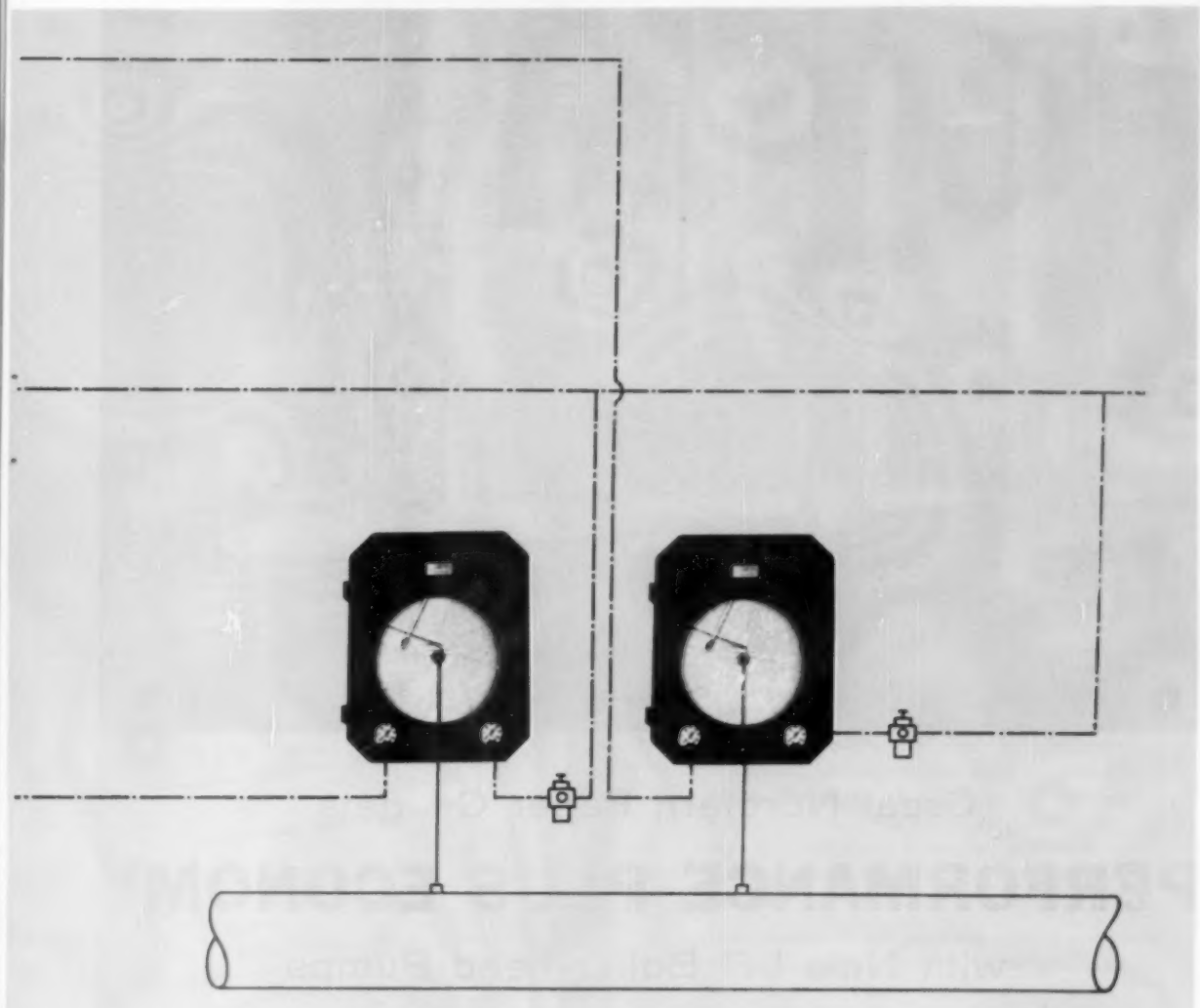
Carburetor-type desuperheaters available with both Steam-Assist and straight mechanical-atomizing systems.

NEW Copes-Vulcan

These high-quality pressure reducing and desuperheating stations offer the latest advances in reducing valves and desuperheaters. They give you an integrated station designed specifically to meet your operating needs.

Copes-Vulcan valves—diaphragm or piston operated, depending on your conditions—give close modulating control. Simplified design means optimum operating characteristics with easy, low-cost maintenance.

The Steam-Assist Desuperheater advances a new principle in reducing steam temperatures. Cooling water and assisting steam are mixed in the exclusive



Schematic installation of a Copes-Vulcan pressure reducing and Steam-Assist desuperheating station.

Pressure Reducing and Desuperheating Stations

swirl chamber, upstream from the point of injection. No large steam bubbles form to cause hammer or vibration. Flow of assisting steam can be automatically reduced as load increases, and shut off completely at high loads where no more than mechanical atomization is needed.

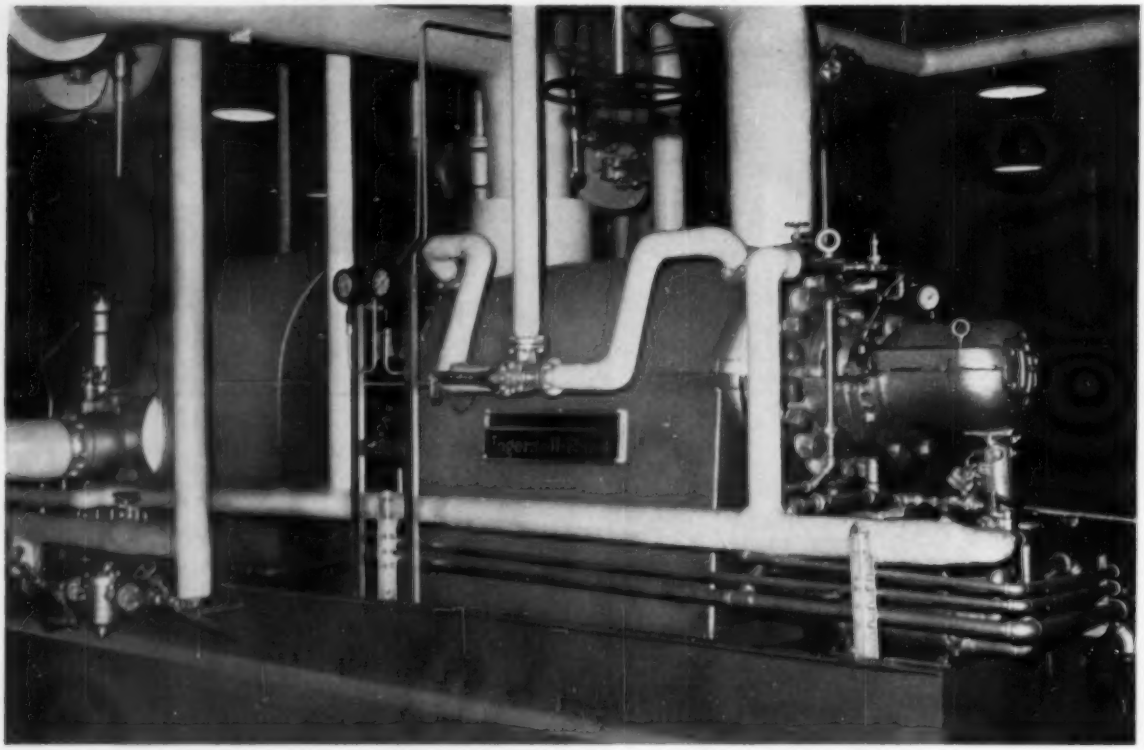
"Packaged" control systems by Copes-Vulcan mean undivided responsibility, custom design and lifetime engineering service. They assure top performance over an unusually long service life.

COPES-VULCAN DIVISION

BLAW-KNOX COMPANY

Erie 4, Pennsylvania

COPES VULCAN



Great Northern Paper Co. gets

PERFORMANCE PLUS ECONOMY

with New I-R Boiler-Feed Pumps

At East Millinocket, Maine, the Great Northern Paper Company is completing a $45,000,000 expansion program that will bring total mill capacity to 1,000 tons of newsprint per day. Constructed by Stone and Webster Engineering Corp., this mill represents the last word in modern paper-making methods and equipment.

In the new and completely modern power plant, boiler feedwater is handled by three identical Ingersoll-Rand 10-stage double-case pumps, each rated 757 gpm, 1554 psi discharge, 287°F. The cylindrical, double-case construction of these Class CHTA high-pressure pumps simplifies maintenance, permits equalized thermal expansion of all internal parts and assures sustained high efficiency. This extra performance means long-range *economy* in heavy-duty service.

Other I-R Cameron pumps are also widely used throughout this ultra-modern mill. In fact you'll find the familiar I-R nameplate on more than 70 units in various plant and process services.

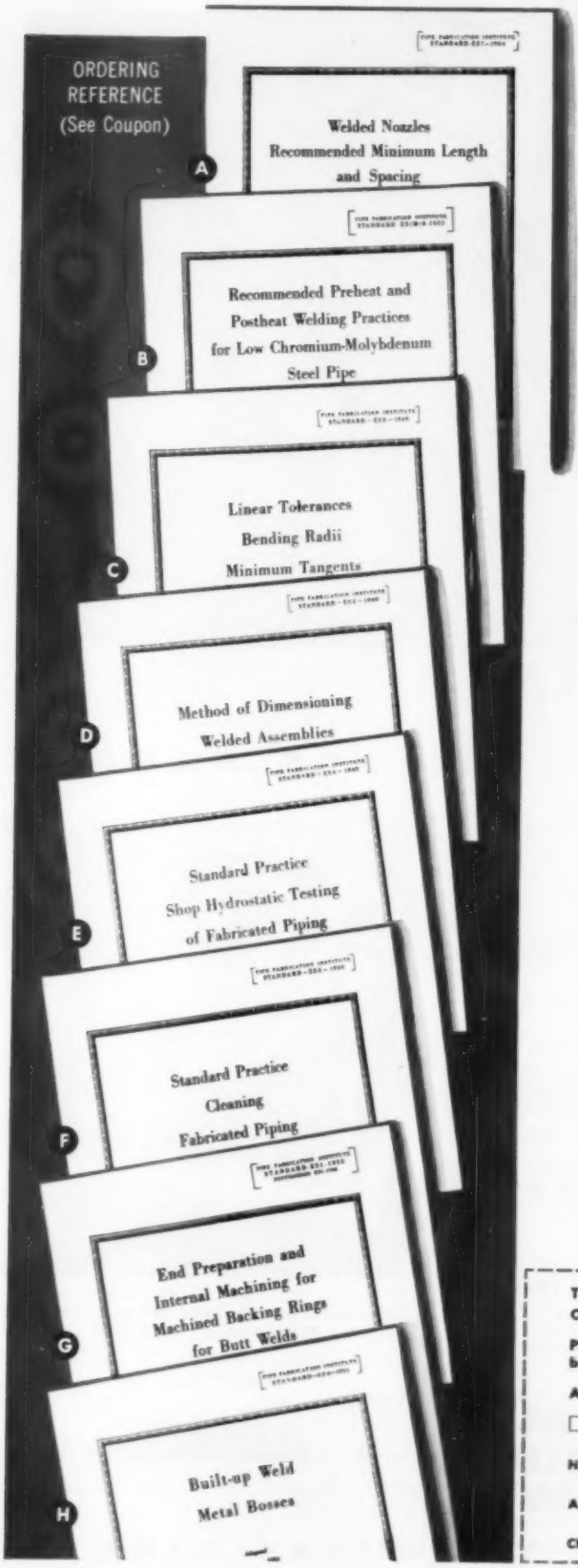
Whatever your liquid-moving requirements, there's an I-R pump that's *right* for the job. Any time you have a pumping problem, your Ingersoll-Rand representative will be glad to help you.

Ingersoll-Rand

11 BROADWAY, NEW YORK 4, N. Y.

10-310

PUMPS • COMPRESSORS • CONDENSERS • DIESEL ENGINES • VACUUM EQUIPMENT • AIR AND ELECTRIC TOOLS



SAVE TIME • CUT COSTS • And Get BETTER PIPING by using THESE PFI STANDARDS

Good standards, understood and accepted by an industry, become a touchstone which speeds operation, improves product and reduces costs. The eight PFI Standards shown here were compiled by the Engineering and Standards Committee of the Pipe Fabrication Institute. They are now widely used by designers, fabricators, contractors and users of pressure piping. They often save time on the drawing board . . . expedite materials delivery . . . save time and money in erection. It all adds up to better piping quicker . . . and maximum value per dollar of cost.

These Standards are available without cost to anyone interested. Simply return the coupon or write on your company letterhead.

THE PIPE FABRICATION INSTITUTE

Devoted to the Technical and Economic Problems in Piping

One Gateway Center • Pittsburgh 22, Pa.

7365

THE PIPE FABRICATION INSTITUTE
One Gateway Center—Pittsburgh 22, Pa.

Please send me without obligation the PFI Standards I have circled below:

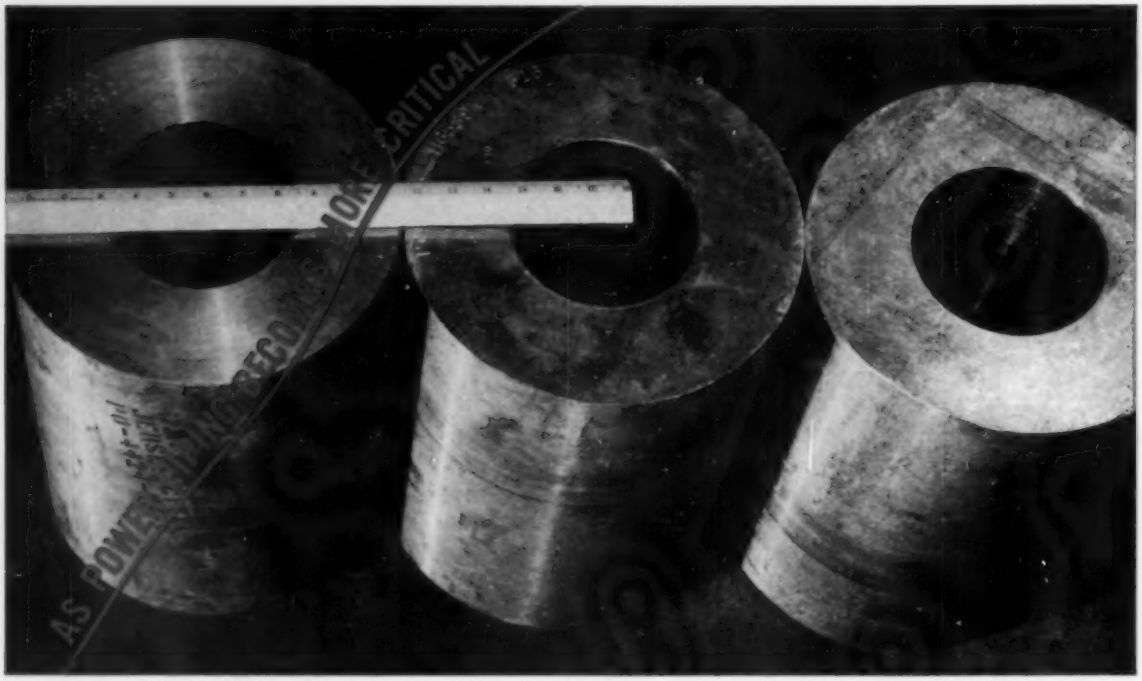
A B C D E F G H

☐ Check here for copies of all future PFI Standards.

NAME_____

ADDRESS_____

CITY_____ STATE_____



Heavy-walled sections of new and existing alloys, most never before used for the purpose, are tested and evaluated by Kellogg toward improving design and performance of main and reheat steam piping.

M. W. KELLOGG METALLURGY KEEPS PACE

With wall thicknesses of main and reheat steam piping for current steam-electric power plants already approaching the upper limits of practicality, supercritical pressures and temperatures present a multiplicity of metallurgical problems to the power piping designer and fabricator. New and stronger stable alloys must be developed, new welding materials found, and new welding techniques and heat treating procedures perfected.

At The M. W. Kellogg Company, new materials containing alloying elements such as molybdenum, cobalt, tungsten, nitrogen, and titanium —in addition to chromium, nickel, and columbium—are now being investigated for long term high pressure service to 1300 deg. F. Most have never before been used for main or reheat steam piping. Heavy-walled sections of these materials are welded, tested, and evaluated by every known technique at Kellogg's Jersey City metallurgical laboratories.

The results of these continuing studies will prove extremely valuable to consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

Sections of piping are welded, using various materials and techniques, and then tested for strength and other characteristics.

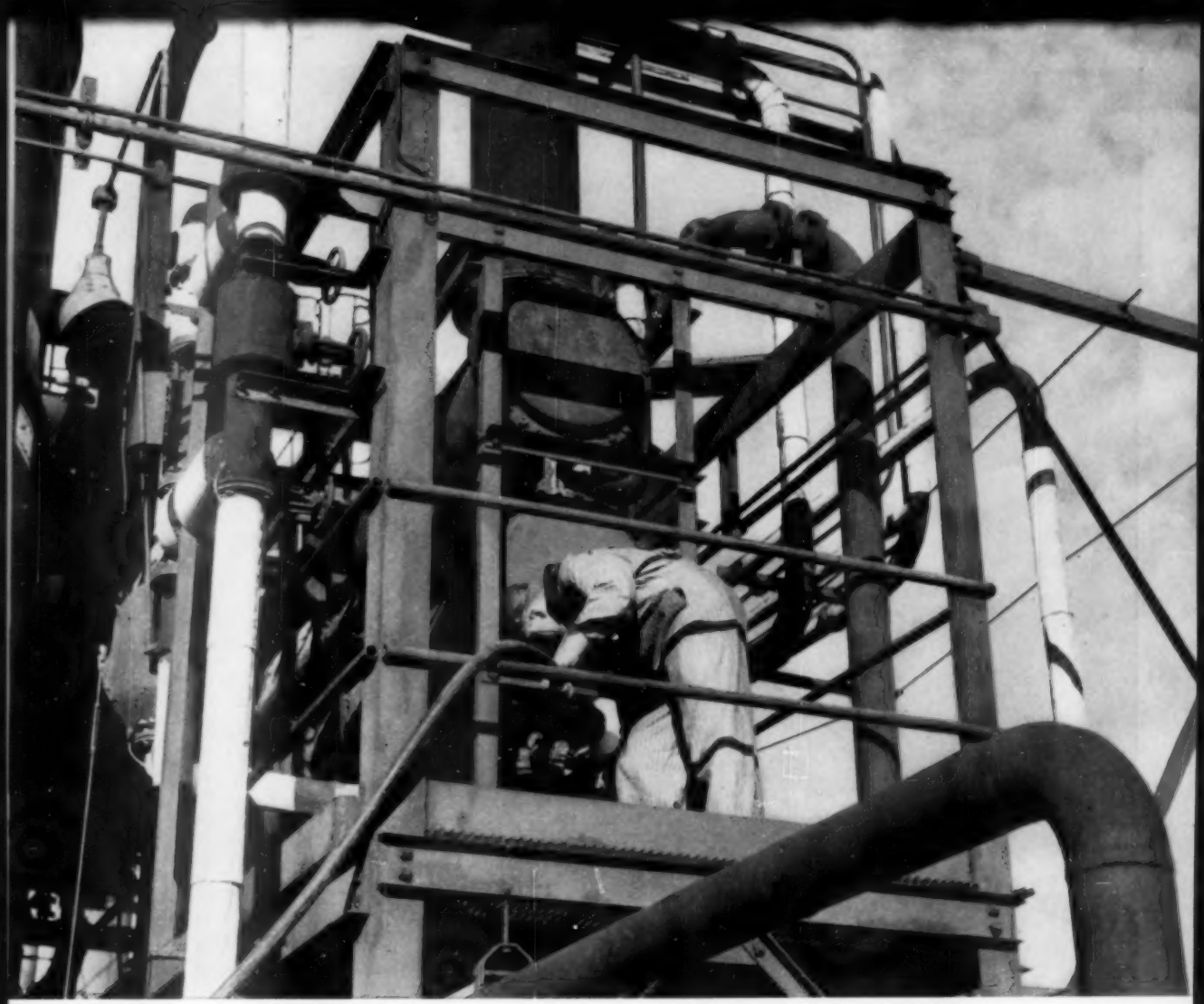
FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N.Y.

The Canadian Kellogg Company, Ltd., Toronto • Kellogg International Corp., London

SUBSIDIARIES OF PULLMAN INCORPORATED

POWER PIPING—THE VITAL LINK



There's too much at stake —clean it right

Chemical cleaning involves costly equipment and often work stoppages. It's a job for experts. Let Dowell protect that equipment and keep production losses to a minimum when you have scale or sludge problems.

In over 15 years our trained engineers have serviced virtually every kind of equipment in plants, mills and refineries throughout industry. In fact, Dowell has cleaned over 10,000 boilers alone!

This experience means lower costs to you—in more thorough work, restored efficiency and less production loss.

Furthermore, Dowell engineers know you value the safety of your men and equipment. Dowell uses only the latest safety equipment and techniques to eliminate hazards and accidents. Our engineers work closely with your safety personnel to establish the safest possible working procedures.

Call the nearest of more than 165 Dowell offices. An experienced engineer will be glad to talk over and help you with your cleaning problems any time — at no obligation. Or write Dowell Incorporated, Tulsa 1, Oklahoma, Dept. C-25.

chemical cleaning service for industry

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

MUD DRUM as opened after one year on line with THE *Nalco* SYSTEM

Unretouched photo of Nalco treated boiler at Georgia Institute of Technology, Atlanta, Georgia

● Calling this a mud drum serves only to identify its location . . . it is perfectly clean after a full year on line. The unretouched photo was taken immediately after the drum was opened. No wash-out was necessary. Not only is the drum free of scale and corrosion . . . Nalco sludge conditioning operated so effectively that even under the static, off-line draining condition, no sludge deposited in tubes or drums.

The Nalco System can get results like these, economically, in *your* plant—regardless of boiler size or pressure. Write or phone Nalco today for action on a complete water treatment program.

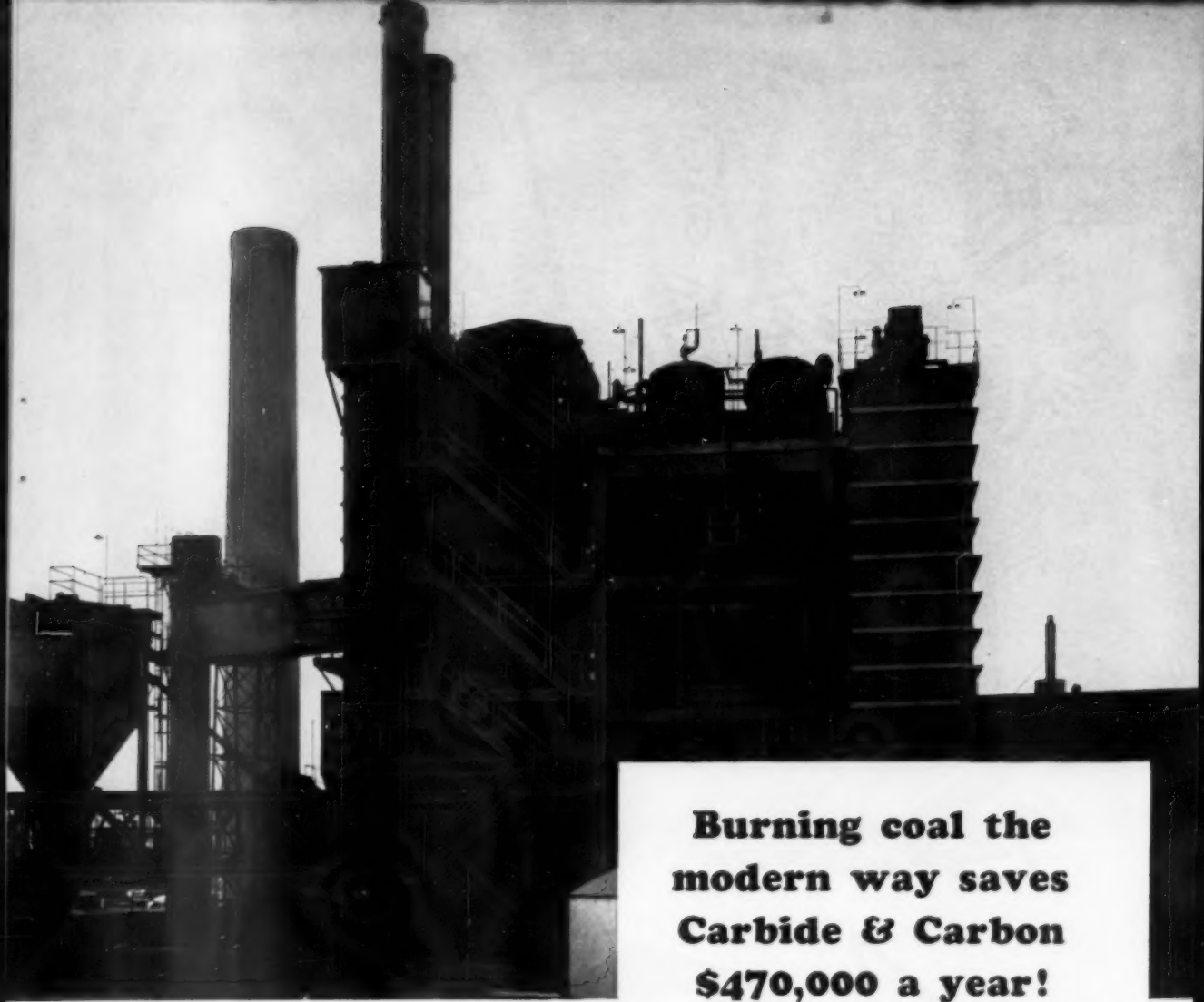
NATIONAL ALUMINATE CORPORATION

Telephone: POrtsmouth 7-7240

6234 West 66th Place • Chicago 38, Illinois

In Canada: Alchem Limited, Burlington, Ontario

THE *Nalco*® SYSTEM . . . Serving Industry through Practical Applied Science



Burning coal the modern way saves Carbide & Carbon $470,000 a year!

Two years ago Carbide & Carbon Chemicals Co. instituted a modernization program in the power department of its South Charleston, W. Va. plant. Utilizing latest steam-generating techniques and equipment, the firm replaced an outmoded installation with a 289,000-lb.-per-hr. boiler fired with pulverized coal, and completely revamped the rest of its power system.

Today, this program has resulted in impressive annual savings. Lower fuel and maintenance costs save $85,000 . . . increased efficiency, $175,000 . . . flyash re-use, $10,000 . . . lower electrical power generation costs, $150,000 . . . lower manpower costs, $50,000—a total savings of $470,000 a year *plus* continuing power service dependability at Carbide & Carbon.

For further information or additional case histories showing how other plants have saved money burning coal, write to the address below.

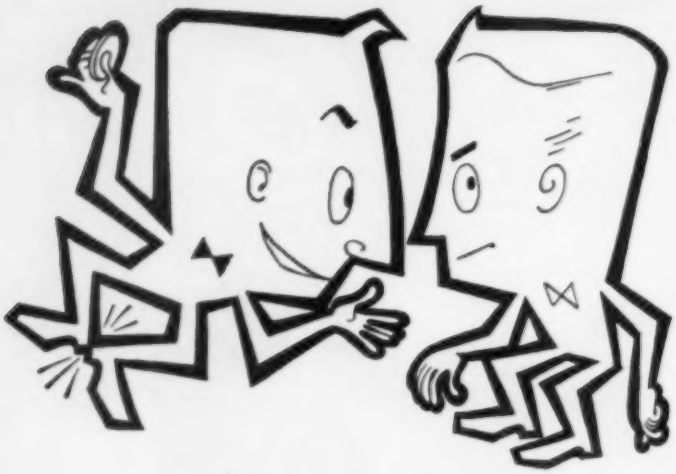
NATIONAL COAL ASSOCIATION
Southern Building, Washington, 5, D. C.

Consult an engineering firm

Designing and building hundreds of heating and power installations a year, qualified engineering firms can bring you the latest knowledge of fuel costs and equipment. If you are planning the construction of new heating or power facilities—or the remodeling of an existing installation—one of these concerns will work closely with your own engineering department to effect substantial savings not only in efficiency but in fuel economy over the years.

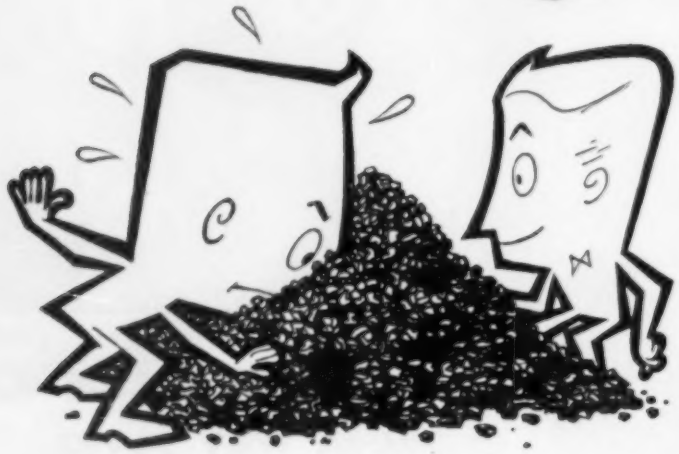
facts you should know about coal

In most industrial areas, bituminous coal is the lowest-cost fuel available • Up-to-date coal burning equipment can give you 10% to 40% more steam per dollar • Automatic coal and ash handling systems can cut your labor cost to a minimum. Coal is the safest fuel to store and use • No smoke or dust problems when coal is burned with modern equipment • Between America's vast coal reserves and mechanized coal production methods, you can count on coal being plentiful and its price remaining stable.



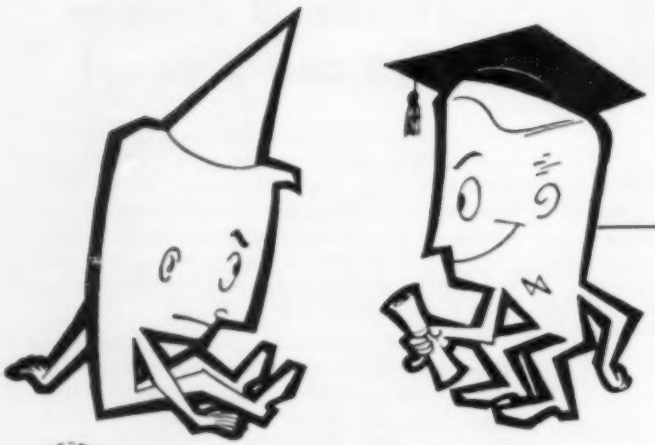
Look! I can buy coal for much less a ton than you're paying.

I used to buy that coal too, but it costs more per million BTU's with a whole lot more in hidden costs.



What do you mean by "hidden costs"?

That coal you're talking about is high in ash. So we were buying ashes at the coal price, paying freight on them from the mine, then paying to have them hauled away. Your "cheaper" coal clinkers; it smokes; it fouls the tubes. That means higher labor costs and higher maintenance. Now I pay more per ton and save thousands of dollars a year.



Coals produced on the C&O are tops in quality.

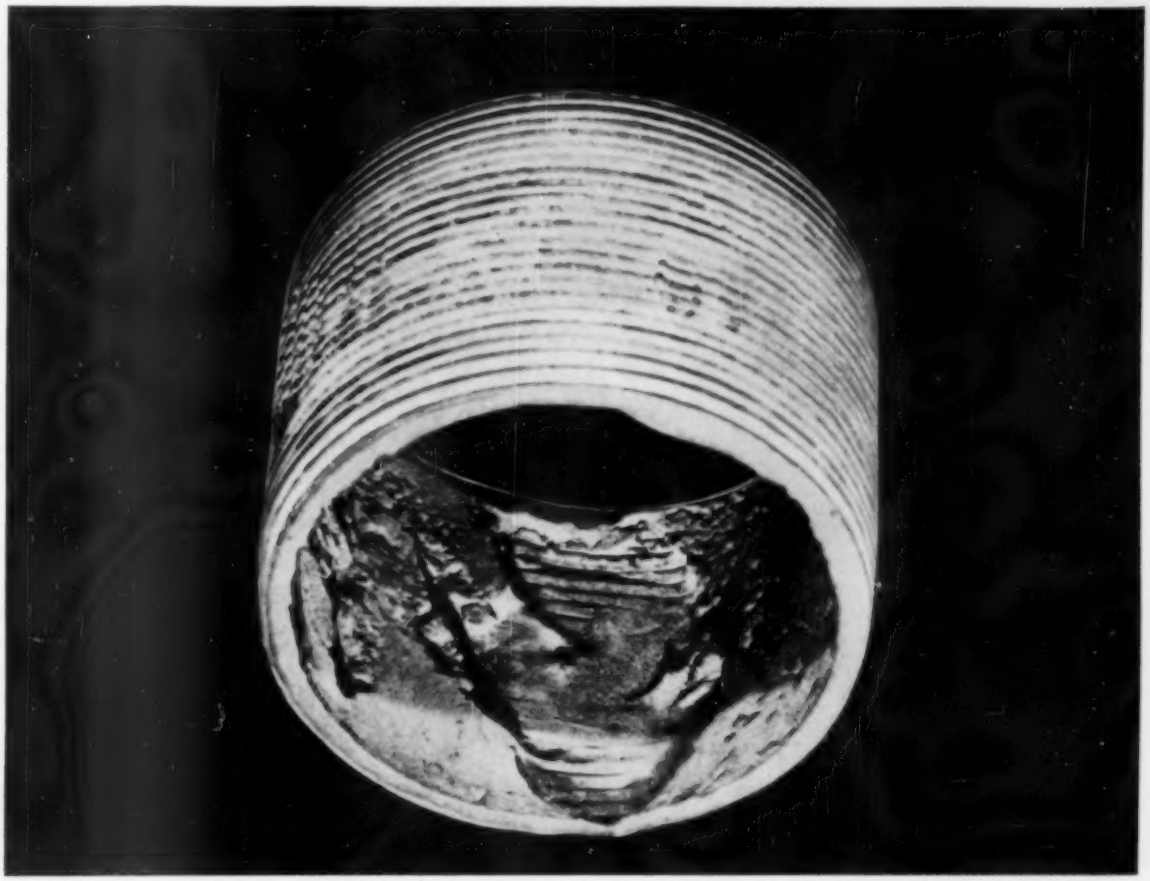
A C&O combustion engineer showed me why this grade of coal would work best in our type of installation and our experience has shown he was right. You'd better get some expert advice. It can save you money, too.

P.S.

There's a lot more to buying coal than the cost per ton. Why not contact coal producers on the C&O to solve your particular fuel requirements, or write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake and Ohio Railway Company, Terminal Tower, Cleveland 1, Ohio.

Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL



Return line corrosion resulting from carbonic acid

ALL pHOULED UP

pH—a symbol denoting the negative logarithm of the concentration of the hydrogen ion in gram atoms per liter. This scale permits the expression of both acidity and alkalinity in units which can be measured by means of a hydrogen electrode.

That's what chemists say about it. Some of the things that power plant engineers say about it are best left unquoted.

A low pH value in condensate can cause a power plant engineer a lot of trouble. When the pH value of water goes below 6.9, it's becoming acid—and when it's acid, it's highly corrosive. Then it begins to eat away at the internal surfaces of pipes and return lines.

Corrosion caused by low pH is most effectively prevented by the application of Dearborn's FILMEEN.* By forming a non-wettable, monomolecular coating on all metal surfaces with which treated steam or condensate come in contact, FILMEEN provides a protective, corrosion-inhibiting barrier between water and metal. By preventing the carbonic acid from touching the metal surfaces, FILMEEN thus keeps the lines corrosion-free.

When you find rusty condensate coming back to your boilers, it's time to see your Dearborn representative. He'll show you how FILMEEN will reduce excessive maintenance, avoid shutdowns and protect valuable equipment in your power plant.

*FILMEEN—U. S. Pat. No. RE-23614 reserves to Dearborn Chemical Company and its licensees exclusive right to the use of octadecylamine for water treatment.

Dearborn®

Dearborn Chemical Company • Chicago 54

COMBATTING CORROSION EVERYWHERE SINCE 1887

Dearborn Chemical Company, Dept. COM
Merchandise Mart Plaza, Chicago 54, Ill.

Gentlemen:

☐ Send a copy of Bulletin 5013-B on FILMEEN.
☐ Have a Dearborn representative call.

Name.....*Title*.....

Company.....

Address.....

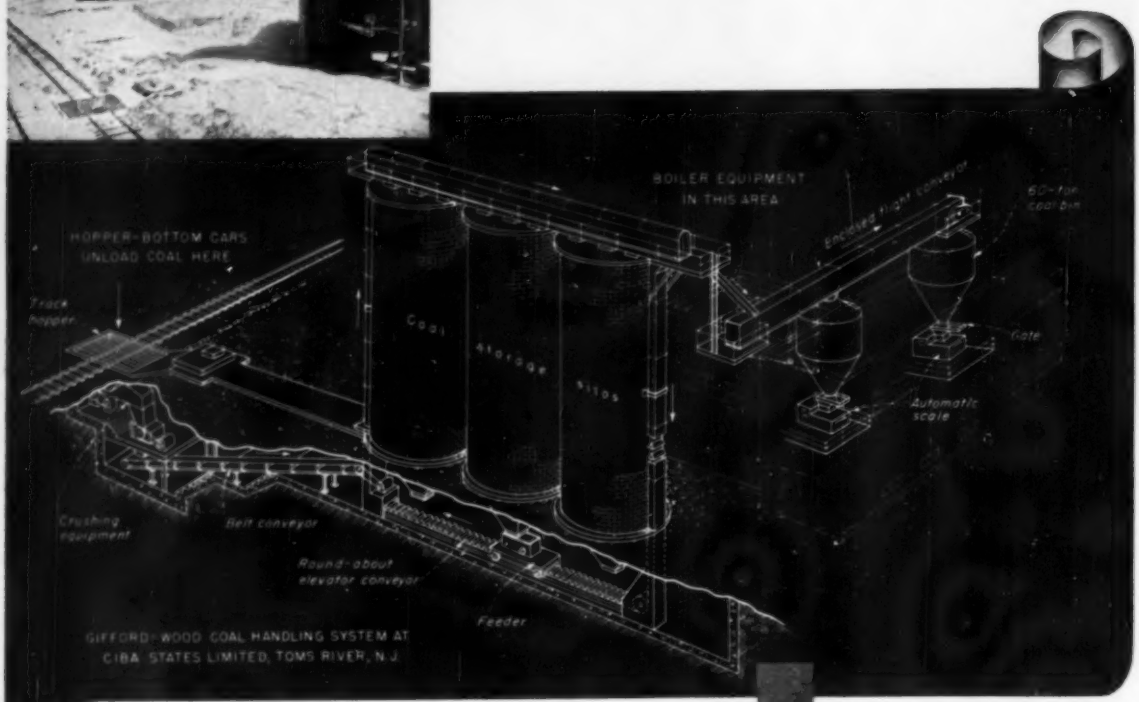
City.....*Zone*.....*State*.....

Enclosed flight conveyor and 60-ton coal bin.

Under-track hopper and coal storage silos.

ANOTHER G-W AUTOMATIC COAL HANDLING SYSTEM...

this time for Ciba States Ltd.



GIFFORD-WOOD COAL HANDLING SYSTEM AT CIBA STATES LIMITED, TOMS RIVER, N.J.

Now nearing completion at Toms River, N. J., is the world's most modern vat-color producing plant—and helping insure maximum power development with top economy will be the most efficient coal handling system, by Gifford-Wood. The system was designed and built by G-W engineers for Ciba States Limited, and includes unloading, storage, and feeding facilities.

For more than 140 years, G-W has met and solved materials-handling problems. This experience, coupled with planned application of the most modern equipment, is at your disposal. This project is only one example of complete design, construction, and erection under one responsibility

For details on this, or other Gifford-Wood coal handling installations, please write for Bulletin No. 300.

As diagrammed, coal passes from hopper cars through crushers, and then by means of belt and bucket conveyors, to silo storage. Transfer of coal from storage silos is by gravity feed into a movable car from which the bucket elevator lifts it, by-passing the storage silos, to an enclosed flight conveyor discharging into bins, which feed through coal scales to pulverizers.

GIFFORD-WOOD CO.

Since 1814
Hudson, New York

New York 17
420 Lexington Avenue

St. Louis 1
Railway Exchange Building

Chicago 6
565 West Washington Street

8756

When You Think of Materials Handling—Think of Gifford-Wood

problems in pressure relief . . .

DEPENDABLE PROTECTION

"Old Faithful"

COCHRANE MULTIPORT RELIEF VALVE with cover removed showing the Multiport Valves that assure smooth, pulsationless operation.

Cochrane

Multiport Relief Valves *offer versatility and safety*

Cochrane Multiport Relief Valves protect the system and its interconnected equipments against too high pressure. Unlike ordinary relief valves, they relieve overpressure g-r-a-d-u-a-l-l-y to atmosphere, they reseat g-r-a-d-u-a-l-l-y, gently—without blowdown, back surge or vapor hammer. Thus, *they maintain system stability even while performing their function of full protection.* Unlike ordinary relief valves, Cochrane Multiport Relief Valves *can be quickly set and reset to suit desired operating conditions.* Cochrane Multiport Relief Valves are made of various materials to satisfy maximum operating conditions. They function equally well handling saturated or superheated steam, air or gas. *They "iron out" pulsations.* Their corrosion-resistant, "vapor cushion" valve discs will not rust, freeze or stick. Here is maximum safety and reliability in a relief valve designed and built for long, continuous service.

For further information concerning Cochrane Multiport Relief Valves, write for Publication 5200.

NOTE: *Cochrane Multiport Relief Valves are adaptable to check, spillover and other services.*

COCHRANE CORPORATION · WATER AND HEAT ENGINEERS · SINCE 1863 · PHILADELPHIA

Cochrane
CORPORATION

Representatives in 30 principal cities in U.S., Toronto, Canada; Paris, France; La Spezia, Italy; Mexico City, Mexico; Havana, Cuba; Caracas, Venezuela; San Juan, Puerto Rico; Honolulu, Hawaii.
Pottstown Metal Products Division—Custom built carbon steel and alloy products

3109 N. 17TH STREET, PHILADELPHIA 32, PA.
NEW YORK • PHILADELPHIA • CHICAGO

Demineralizers • Hot Process Softeners • Hot Zeolite Softeners • Dealkalizers • Reactors • Deaerators • Continuous Blowoff Systems • Condensate Return Systems • Specialties

AD 13.10

N. Y. State Elec. & Gas Corp.
Michling Station

If your operations depend on piping you can depend on Shaw

Florida Power & Light Co.
Cutler Station

Metropolitan Edison Co.
Titus Station

Potomac Electric Power Co.
Buzzard Point Plant

Ind. & Mich. Electric Co.
Tanners Creek Plant

Potomac Electric Power Co.
Potomac River Gen. Sta.

Pennsylvania Electric Co.
Seward Station, Unit 5

SHAW

piping specialist in Power Plant Construction

If you are concerned with the construction of a modern power plant, you realize the absolute need for specialization in all phases of the work. Particularly is this true of the fabrication and installation of the intricate piping which such a project requires. Only a specialist can provide the best in piping; that is, piping which is custom fabricated, properly installed, safely and economically designed for your specific needs. Shaw is such a specialist, qualified through years of experience to fabricate and erect power plant piping for any pressure and any temperature you require. Since 1893, Shaw has devoted its resources, its talents and its energies to this kind of specialization. That's why we say—if your operations depend on piping, you can depend on Shaw.

Shown here—and the names included are foremost in the industry—are some of the many power plants in which the piping is Shaw-fabricated.

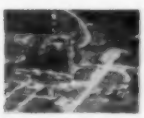
Del. Power & Light Co.
Indian River Station

Ohio Power Company
Phila Station, Unit 6

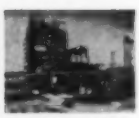
Ind.-Ky. Electric Corp.
Clifty Cr. Sta., Units 1-6

Houston Lighting & Pr. Co.
Greens Bayou Station

Houston Lighting & Pr. Co.
Deepwater Station, Unit 7



Houston Lighting & Pr. Co.
Webster Station



Houston Lighting & Pr. Co.
Sam Bertron Station

Ohio Power Company
Muskingum R. St., Units 1-2

Appalachian Elec. Power Co.
and Ohio Power Company
Philip Sporn Plant

BENJAMIN F.

SHAW

COMPANY

Main Offices and Plant: Wilmington, Delaware

Piping Fabrication and Installation Since 1893

Editorial

The British Electrical Generation Picture

Some eighteen months ago the Minister of Fuel and Power appointed a special committee under the chairmanship of Sir Edwin Herbert to inquire into "the organization and efficiency of the electricity supply industry in England and Wales" as it was developing under the direction of the British Electricity Authority, now known as the Central Electricity Authority. The report of this special committee is most revealing.

In brief the committee's major point was the feeling that the chief officers of the Central Electricity Authority were overwhelmed with day-to-day tasks and should be relieved both of the executive responsibility for generation and transmission and of the present vague responsibility for the industry as a whole. They should concentrate their energies, rather, on review of policies, programs and expenditures. The actual construction and operation of power stations and of the transmission system, for example, should be assigned to a new organization. Such a reassignment, it was believed, would overcome the delays that are part and parcel of the present organization and would remove the irritation produced by an overly centralized control upon the existing divisional directors.

There were other, lesser weaknesses described such as the abrogation of the control of Authority business by committees, as originally envisaged, to the more general practice of committee chairmen and deputy chairmen exercising this control. Further, there was felt to be evidence of too many men down the line having too little to do. One strong recommendation called for inviting foreign manufacturers to bid for plant needs to induce keener trading by British firms. The need for more research was stressed since the various Area Boards were held to be too dependent upon the manufacturers for technical progress.

All the above indicates a healthy, realistic appraisal of a governmental agency which has, in the main, done a creditable job in a very difficult area. It must always be remembered, however, that actual performance of any organization no matter how excellent its paper organization must accede to the old adage: "the proof of the pudding is in the eating." This first sampling in the form of a committee report may indicate that the pudding's ingredients rather than the cooks are in need of a change. The objectives of the Electricity Authority as originally established apparently are too broad to be encompassed within the framework of a single body, in our opinion.

Our view of the public utility industry, as we see it in the U.S.A., reveals an enterprise with so many ramifications we feel it would be a burden past all comprehension for any central agency to both rule it and run it. As such we could offer no constructive comments on how to broaden the organizational structure of the CEA to meet such a task. Rather we sympathize with the gist of the Herbert Committee report and believe more decentralization is necessary for vigorous growth of the electric industry in England and Wales.

An Undersold Asset

At the recent AIEE Winter General Meeting there was considerable discussion of the problem of attracting young graduate engineers to the electric utility industry. With respect to electrical engineering curricula, mention was made of the number of colleges which had dropped the power option and of the relatively small number of students choosing this option in the schools which still offered it. The utility industry was criticized on the grounds that (1) it had not placed its opportunities in terms of glamorous technicolor, as had the electronics industry, and (2) it had not placed enough stress upon research.

Yet to those who are well aware of the continuing progressive engineering accomplishments of the electric utility industry, these criticisms are worthy of serious thought. Sometimes people—even civilizations—take progress for granted in the same sense that freedom is undervalued until there is danger of its loss. It is the dramatic events that make up history that bring to the mind of the public the enduring value of what otherwise is merely accepted casually.

Something akin to this may be needed in recruiting engineering students for the electric utility industry. Progress in power generation is not just an accident of nature. It is the result of planned effort of the utility industry and its consultants and suppliers. A most important catalyzing agent that links these efforts together is the freedom of interchange of information among the participants. The work of the many technical committees, including the power generation committees of the Edison Electric Institute and the Association of Edison Illuminating Companies, contributes to this free exchange of data. But how many people outside of the electric utility industry and how many student engineers are aware of the role of such activities in promoting progress? Freedom of interchange of information remains an undersold asset of the electric utility industry.

The Use of the Suction Pyrometer in Pulverized-Fuel-Fired Furnaces*

By A. M. GODRIDGE and G. G. THURLOW

Physics Department, British Utilization Research Assn.

Two factors complicate the use of the suction pyrometer in ash-laden gases: (1) Deposits forming on the radiation shield system can decrease the emissivity of the surfaces and hence seriously impair the accuracy of the instrument. (2) Certain types of radiation shields rapidly become blocked in temperature ranges where the dust is sticky, making observations difficult to obtain. The form in which the ash collects on the instrument depends on temperature. Special heads have been developed for use in certain temperature bands. At higher temperatures still, where the slag is molten, different problems are met with, and briefly discussed.

THE measurement of gas temperatures in industrial furnaces is not easy and, though various methods have been proposed or are in the course of development, few accurate instruments are available even for intermittent testing and experimental use. Of these, the suction pyrometer is the most common and an all-metal version of the instrument which will give accurate reliable temperature measurements up to 2200 F (1200 C), e.g., at the exit to the combustion chamber of water-tube boilers and similar appliances, has been reported (1).[1] Some preliminary notes on the use of this instrument with refractory heads at higher temperatures were given in the earlier report. The experimental work described, however, was restricted to tests on stoker-fired furnaces and it was stressed that, owing to blockage and the build-up of deposits round the instrument, its use in its original form on pulverized-fuel-fired boilers and other appliances having a high dust burden is difficult. The present paper discusses the use of the suction pyrometer in such "dirty" gases.

In a suction pyrometer, the temperature measured by a thermocouple is made to approach very close to that of the gas in which it is immersed by sucking the gas across the thermocouple at a high velocity, so increasing the convective heat exchange. At the same time, a system of shields placed round the thermocouple reduces the radiation between it and surrounding surfaces, which are generally at a different temperature from the gas.

In the customary design of shield system the thermocouple is surrounded by a series of concentric rings, preferably finned, the gas being drawn down the annular spaces between them. The outer shield takes up a temperature between those of the gas and of the surrounding surfaces. The next inner shield then exchanges heat by radiation not to the wall but to the inner surface of the outer shield and, as this will be closer to the gas temperature than the surrounding walls, the radiation is less and the temperature of the inner shield is still closer to the gas temperature. A similar argument applies to all subsequent shields and finally to the thermocouple sheath itself.

Dust in the flue gas can either collect on the probe and shield system, similar to the way deposits build up on the boiler walls and tubes, or be drawn into the shield system with the gas. The first and obvious effect of this dust is to block the gas passages, so reducing the flow and, hence, velocity over the thermocouple. It is also possible that the deposit layers on the radiation shields can change significantly the amount of radiant heat exchange between them by altering the emissivity of these surfaces. Generally speaking, the deposits raise the emissivity with the result that the shields would be less effective.

The actual deposit layer on the outside of the shields acts as an insulating layer and will tend to improve the accuracy of reading. The increased thermal capacity, however, will reduce the speed of response of the pyrometer and can, eventually, make it too sluggish to be of value.

The rate of build-up and form of the deposit layer is dependent both on the quantity and the properties of the particulate matter present in the gas stream. The quantity and size of fly-ash particles vary from boiler to boiler, being more plentiful and generally smaller in pulverized-fuel-fired units than in stoker-fired units. Table I summarizes some typical values, collected from various sources, for the dust burden in different appliances as measured at the dust-extracting equipment.

TABLE I—COMPARISON OF DUST BURDEN IN VARIOUS APPLIANCES

Method of Firing	Per Cent of Ash Passing through the Furnace as Dust	Per Cent of Dust Smaller than 76μ (200 Sieve)
Pulverized fuel (dry bottom)	70–80	90–95
Pulverized fuel (slag tap)	30–50	About 90
Traveling grate	10–12	40–45
Retort stoker		
Spreader stoker	20–40	60–65

In the dry-bottom pulverized-fuel-fired furnace discussed later, the proportion of the ash in the fuel carried forward through the combustion chamber was 81 per cent at mcr (maximum calorific rating) and 77 per cent at ecr (efficient calorific rating). Corresponding figures for the continuous slag-tap furnace are not available.

The high dust concentration met with in the pulver-

* Reprinted by special permission from the December 1955, Vol. XXVIII, No. 179, *Journal of the Institute of Fuel*, 18 Devonshire St., London W.1, England.

[1] Numbers in parentheses refer to Bibliography at the end of the article.

Fig. 1—Blockage and deposit build-up on the surface of any temperature measuring head poses problems for suction pyrometers in pulverized fuel furnaces. Probe, left, shows deposits at 1600 F; middle, 2000 F; right, 2900 F

ized-fuel-fired units compared with stoker-fired units is clear from Table I. The amount of, and form in which, dust collects on and in the pyrometer is, however, primarily determined by its adhesive properties. If the ash is solid, it has little tendency to stick and experience has shown that, under these conditions, little trouble is found when using the suction pyrometer. If the gas temperature, however, is high enough for the particles to be plastic and sticky, they will adhere both to one another and to any surface they come into contact with, resulting in the rapid formation of sintered or "birdnesting" deposits. These consist of an agglomeration of particles, slightly deformed and sintered together where they are in contact. The deposits can often be crumbled between the fingers, although with increasing gas temperatures, the deposits become more dense, coherent and strong. These deposits are bulky and grow fast and, as will be shown, cause most trouble.

If the temperature is high enough, the ash will be completely liquid and form a film which solidifies to a hard, dark-colored glaze. The problems of temperature measurement under these conditions are in a class of their own and appreciable work on them is being carried out, particularly in the steel industry. Though a short note on the authors' experiences when testing at these conditions is included under *Temperature Traverses*, most of the present paper is concerned with the range of temperatures in which sintered deposits occur. Fig. 1 shows the appearance of the original refractory head after being used in the three temperature bands.

As an indication of the levels of temperature at which these conditions may be expected, some examples of the properties of four coals under semi-reducing or oxidizing conditions are given in Table II. It will be seen from these that the ash particles begin to get soft about 2000 F (1000 C). Below this temperature, the use of the suction pyrometer is straightforward and procedures given in reference 1 can be used. Above this temperature and up to 2550 F (1400 C) or more, trouble due to sintering deposits will occur while, at higher temperatures still, liquid slag may be met with.

TABLE II—FUSION PROPERTIES OF VARIOUS ASHES (MARSKELL AND PRATT (2)

	—Semi-reducing Atmosphere—		—Oxidizing Atmosphere—	
Coal	Initial Deformation Temp., Deg C	Fluid Temp., Deg C	Initial Deformation deg C	Fluid Temp., Deg C
A	1150	1280	1280	1400
B	1150	1380	1390	.....
C	1100	1380	1300	Over 1400
D	1070	1310	1320	Over 1400

It should be noted that the relevance of fusion temperatures determined in the laboratory to actual conditions is suspect. This point is considered again later under *Temperature Traverses*.

Description of the Suction Pyrometer

The design of pyrometer used in these tests was similar to that previously described. The probe, Fig. 2, consists of a 10 ft × 2 in. outside diameter water-cooled probe down which the gases are sucked by means of a portable centrifugal blower coupled by a length of flexible tubing to the end of the probe. The probe is so designed that the pressure-drop down it is not large, enabling a high gas velocity to be maintained over the thermocouple. A Pt/Pt-Rh thermocouple passes up the center of the probe to project 2–3 in. beyond the water cooling, where it is enclosed in a sheath. At gas temperatures below 2200 F (1200 C), heads manufactured in Inconel 76/15 Ni-Cr steel, having a melting range of 2540 to 2600 F (1395 to 1425 C) can be used, Fig. 3, consisting of four finned shields which form a detachable unit 6 in. long, fitted by a bayonet socket to the end of the water-cooled probe. The thermocouple is protected by a closed metal sheath, which is also finned.

For gas temperatures above 2200 F (1200 C) the metallic head and sheath must be replaced by refractory components, the original design being shown in Fig. 4. The thermocouple is protected by a plain alumina sheath, closed at one end and cemented into a metal cap at the other. This screws on to the metal covering round the thermocouple wires at a position about 6 in. within the water-cooled section. The radiation shields consist of two concentric refractory tubes cemented on to a metal base which fits into the water-cooled probe by means of a bayonet socket. Either the metal or the refractory head or similar versions can be used at temperatures below about 1850 F (1000 C), dependent on the properties of the ash. Thus, on the dry-bottom, pulverized-fuel-fired furnace tested, the metal head was used successfully when traversing between the primary and secondary superheaters (see *Temperature Traverses*).

The effect of dust on both the metal and the refractory heads at slightly higher temperatures is shown in Fig. 5. It will be seen that the rate of blockage is such as to make actual temperature measurements very difficult and slow, if not impossible. The refractory head had a "life" before complete blockage at the conditions of test of about 18 minutes, while the metal head only lasted about 3 minutes. Effects of this order were observed when using these heads on pulverized-fuel flames within the temperature band where the dust particles were "sticky."

Test Procedure

The experimental work described in this paper was carried out on two pulverized-fuel-fired boilers. Details of these boilers are summarized in Table III, while line diagrams of the combustion chambers are given in Figs. 6 and 7. Wherever possible, precautions were

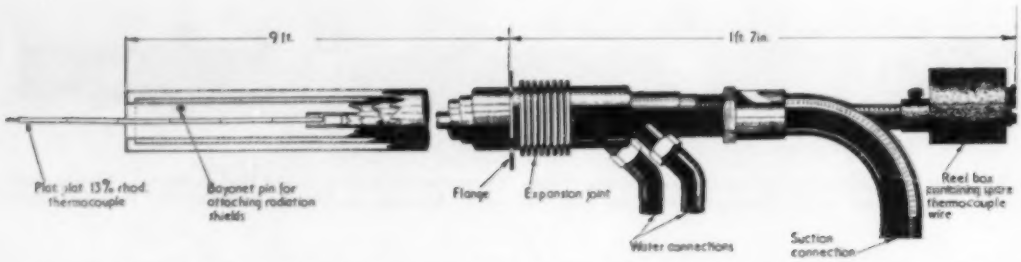


Fig. 2.—Diagram, above, of probe shows a thermocouple, (1) a bayonet pin for attaching shields, (2) a flange, (3) an expansion joint, (4) water connections, (5) the suction connection, (6) and a reel box, (7) containing spare wire

taken to allow for changes in the furnace temperature during the tests. A "control" instrument was inserted into the furnace beside the pyrometer and held at a constant depth equal to approximately half that of the full traverse of the suction pyrometer. To avoid the need for excessive services (water, electricity, etc.) the control pyrometer used in the dry-bottom furnace consisted of a Pt/Pt-Rh thermocouple encased in an Inconel metal sheath. In the slag-tap furnace a second pyrometer, as previously recommended (1), was used as a control. The temperature measured by the control and the suction pyrometer were recorded alternately at 6-second intervals on an electronic recorder. By considering the difference between these two temperatures, effects due to changes in boiler temperature level were approximately eliminated. It was impossible to carry out this procedure on some occasions at the higher gas temperatures explored owing to practical limitations and, in these cases variations in furnace temperature with time cannot be allowed for.

TABLE III—DESCRIPTION OF TEST BOILERS

Type	Tangentially-fired, dry-bottom, pf boiler	Continuous slag-tap, pf boiler
Load, mcr	320,000-lb per hr	525,000-lb per hr
Steam conditions	625 psi at 875 F	1275 psi at 975 F
Ash-fusion temp. of fuel used	2310–2350 F (1270–1290 C)	2280–2370 F (1250–1300 C)

The use, in this type of work, of automatic temperature recording is to be recommended.

The Use of Filters

The use of nichrome wire-gauze filters placed over the standard metal heads to reduce blockage was first studied. The cylindrical filter, closed at one end, protruded over the end of the radiation shield and could be varied from a "tight fit," when the closed end of the gauze shield was in contact with the open end of the radiation shield, to a "loose fit," when the closed end was approximately 2 in. away from the open end of the radiation shield, so giving a large area of gauze for gas flow.

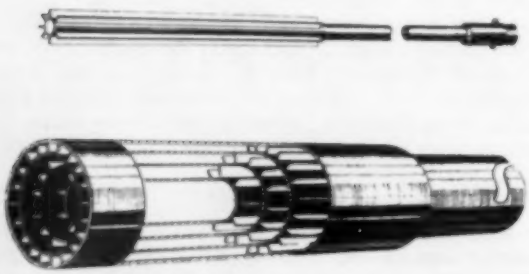


Fig. 3—Finned radiation shields, bottom figure, 6-in. long, are fitted to the probe and a metal sheath to the thermocouple, top.

The results of these tests are summarized in Fig. 8, where the temperature of the suction pyrometer has been plotted relative to the reading of the control thermocouple. It will be seen from Fig. 8 that spot readings are possible with the uncovered metal shield and, from the agreement which was found between observations when using the metal and refractory shield at this point it is reasonable to assume that the peak reading is (within a few degrees) the true temperature. With the metal shield, however, the observed reading drops rapidly. A gauze filter with a large surface area would appear to extend the time when reasonable steady readings are possible, though the cooling caused by the gauze makes the reading lower in this case by about 105 F (60 C). The magnitude of this error could, however, be assessed for any particular installation by a spot comparison without a filter, preferably at two or three distances into the boiler. The filter which fits tightly over the end of the head is obviously of no use, as it causes a large fall in observed reading and rapidly becomes blocked.

These tests showed that frequent cleaning of the heads is necessary in order to traverse on pulverized-fuel-fired boilers with the orthodox metal heads at temperatures where the dust is sticky. The use of suitably placed, easily removable gauze filters over the heads enables in certain instances quicker readings, though at a lower efficiency,[2] to be obtained.

It became apparent in the early stages of these tests that the gas flow through the instrument should not be reversed in an attempt to clear blockage. The cold gas cools the radiation shield, causing the sticky fly-ash on the shield to set solid and to block it completely.

Similar conclusions to the above apply to the use of filters on refractory heads.

The Use of Thick Refractory Heads

It is easy to construct a fairly complex shield system in metal but when it is necessary because of the tem-

[2] "The term "efficiency" of a pyrometer is defined, as in previous papers (1, 3), relative to the reading the pyrometer would give with no suction applied: i.e., the efficiency is given by:

$$\eta = \frac{\theta_0 - \theta}{\theta_0}$$

where θ_0 = difference between true temperature and that observed by a simple sheathed thermocouple, dimensionally equivalent to the pyrometer; and θ = difference between true and observed temperature of the pyrometer.

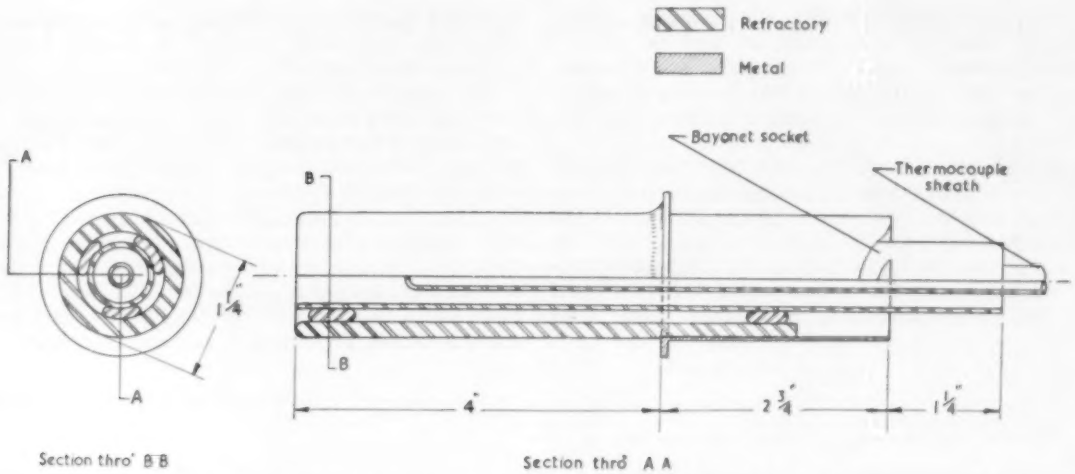


Fig. 4—Gas temperatures above 2200 F require a different head from the metallic one, Fig. 3. Above is the original 2-shield refractory head employed in the reported tests. Section through BB is shown in (a) and through AA in (b)

peratures involved to build the head of refractory, constructional difficulties arise. In theory, however, it is possible to get a high accuracy comparable with that of a complex metal head with a fairly simple refractory head, owing to the low thermal conductivity and emissivity of most refractories. As the efficiency of the shield is dependent, not only on the emissivity, but also on the thermal resistance offered by the head, a thick cylinder of a material of low thermal conductivity with a hole bored down the center would act as a form of radiation shield and this suggests a new approach to the design of pyrometer heads. The efficiency of orthodox shield systems, however, is greatly improved by convective heat transfer between the gas and the surfaces in the annular spaces between the shields.

Without some such heat input, the thermal conductivity of a "thick" shield would need to be very low to give an equivalent value to even a simple series of shields. Any gas passages through the thickness of the block such as a ring of holes, will improve the efficiency and will have an important effect in reducing the time taken for the head to respond to changes in temperature.

An actual comparison of "thick" and the more orthodox complex radiation shield is not straightforward and necessitates the evaluation of the efficiency of each individual design.

Some general comments can, however, be made, as follows: (1) The efficiency of a complex radiation shield drops rapidly with increasing temperature. The efficiency of a "thick" head depends to a large extent on the thermal conductivity. In general, this rises slightly (and hence, the efficiency will fall) with temperature, though the reverse occurs with some refractory materials. (2) The efficiency of a thick head is not nearly so dependent on emissivity as is that of the complex radiation shield: only the outer and inner surfaces being affected. Its efficiency should therefore, be less affected by deposit formation and should give reasonable service in conditions where the more orthodox radiation shields are unsatisfactory.

(3) The response of a thick head will be slower than that of a complex radiation head. This could be improved somewhat, however, by a ring or rings of holes through the head as previously described.

(4) The thick-head type of design will be more robust, an important consideration in practical use. The area of the suction holes can be kept relatively large and these, being circular, should, further, be easier to clean.

With these considerations in mind, the heads described in the following sections were designed and constructed.

Design of Heads

A sectional view of four refractory heads cut from Super Selfrac bricks is shown in Fig. 9. These bricks were used as they may easily be shaped with a hacksaw and soft drill. The dimensions of the heads are given in Table IV. The heads were cemented on to a two-pin bayonet socket with quick-drying cement and fitted in the normal way to the end of the water-cooled probe.

Effect of Blockage

The results of tests on these four heads are summarized in Fig. 10, where the temperatures measured with the various heads are plotted against time. For ease of comparison, the observed temperatures have been plotted

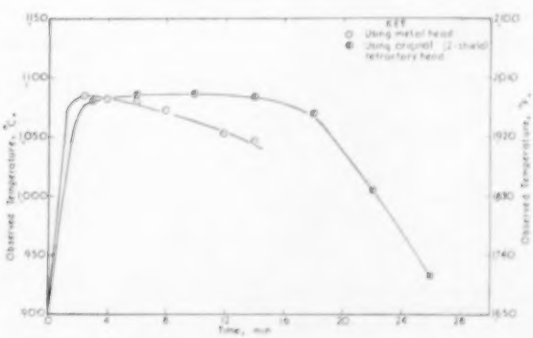


Fig. 5—Blockage on both metal and refractory heads occurs at higher gas temperatures within a matter of minutes

in each case as differences from the maximum reading observed, under the same conditions, with the original (2-shield) refractory head. The simple sheathed thermocouple used as a control showed that there was no appreciable change in furnace temperature between comparative tests.

Fig. 10 shows that: (1) the thick head with the large bore gave readings closer to the true temperature than the head with the small bore; (2) the accuracy of the reading was improved by the circle of holes round the shield; (3) the "life" of the large-bore heads before blockage was appreciably better than with either the original (2-shield) or the small-bore thick heads. Later tests confirmed that runs up to 60 minutes can be carried out before any appreciable falling-off in reading becomes apparent, when using either of the two large-bore heads.

It is apparent that the shield having a large bore and four holes down which suction may be applied gives the most accurate temperature reading of the new heads and has also a reasonably long life. This type of head may be readily cleaned on removal from the hot gas stream. It is probable that a head having a large bore and six holes would be even more accurate, but as the fragility of the head increased with the number of holes, this variation was not attempted. All further tests were therefore conducted with large-bore four-holed heads, these being made both from Super Selfrac and zircon bricks.[5] The

[5] Thermal conductivity of zircon, at 900 C, about 0.005 cgs units; at 1100 C, about 0.0045 cgs units.

TABLE IV—DETAILS OF MODIFIED (THICK) SUPER SELFRAC REFRACTORY HEADS[6]

No.	Length, In.	Diameter, In.	Dimensions of Ring of Holes, In.	No. of Holes
1	6	2¼ O.D., ⅜ I.D.	⅛ in. diameter holes on 1⅜-in. pitch circle	6
2	6	2¼ O.D., ⅜ I.D.	None	0
3	6	2¼ O.D., ¾ I.D.	⅛ in. diameter holes on 1½ in. pitch circle	4
4	6	2¼ O.D., ¾ I.D.	None	0

[6] Thermal conductivity of the Super Selfrac about 0.0011 cgs units at 600 C, increasing to about 0.0015 cgs units at 1000 C.

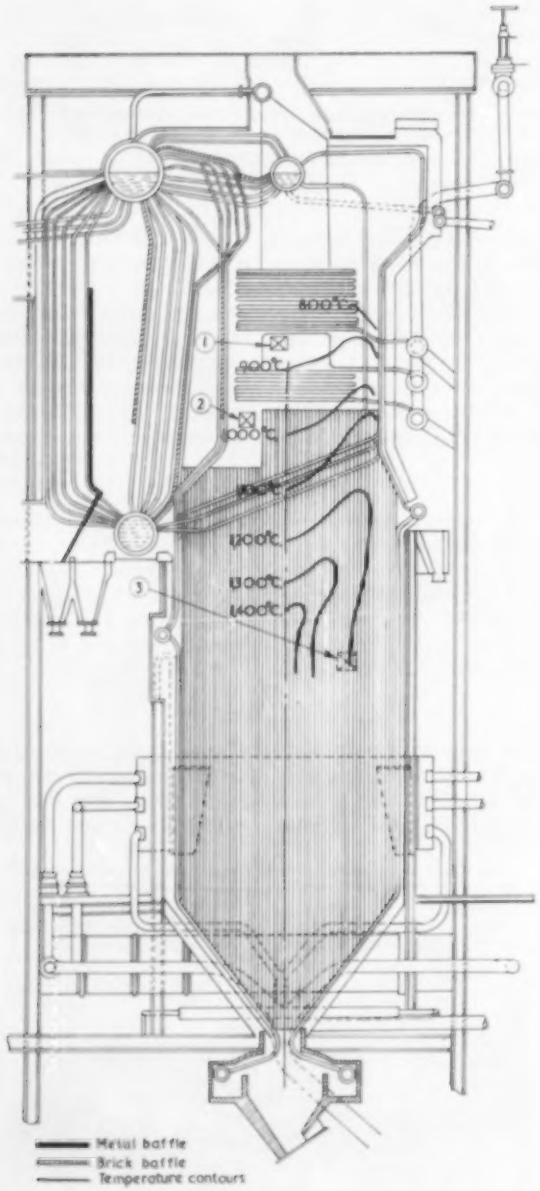


Fig. 6—Dry-bottom, pulverized-fuel furnace tangentially-firing coal of 2310–2350 F ash fusion temperature was tested.

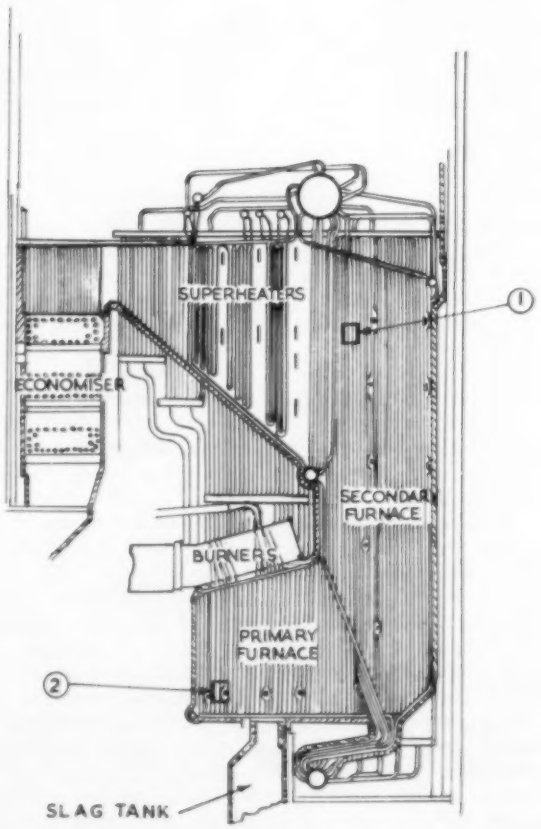


Fig. 7—Continuous slag-tap pulverized fuel furnace burning a 2280–2370 F ash-fusion coal served for a second experiment

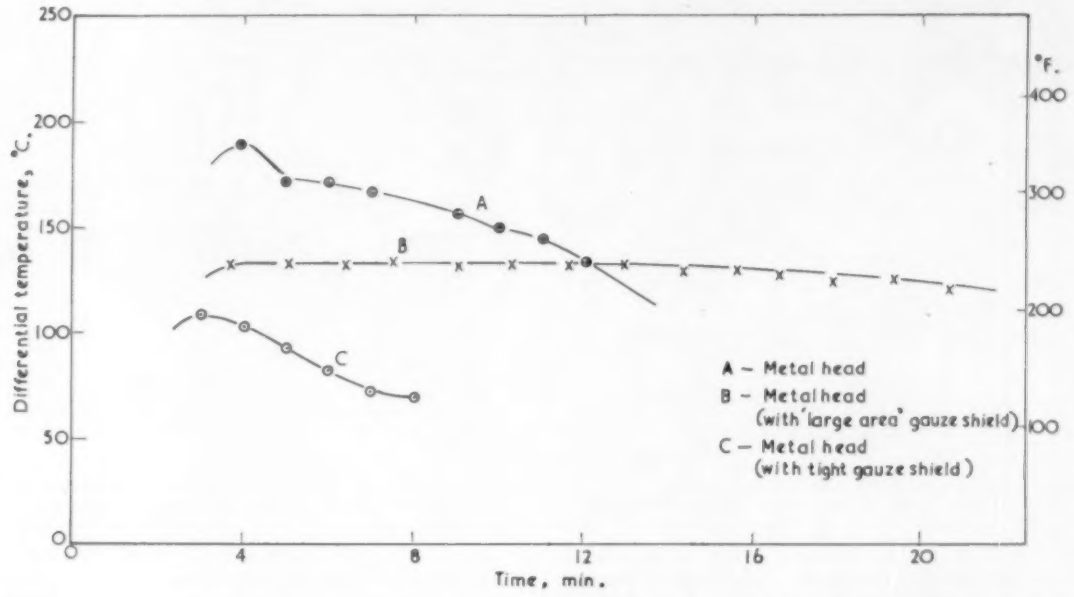


Fig. 8—Nichrome wire-gauze filters over the metal heads was suggested and tried to reduce blockage at about 2000 F. Results show above, A, for the plain metal head; B, for a large area or loose-fit filter; C, for the tight gauze filter

zircon heads were machined from solid cylinders ($2^1/_2$ in. diameter × 4 in. long), and gave a very strong and mechanically robust head, which stood up to practical use without damage. Both the Super Selfrac and the zircon heads could be used for time periods of up to 60 minutes before appreciable dust blockage occurred.

Determination of Accuracy

The accuracy of the large-bore four-hole design of head was determined by three independent methods: by comparison with the original (2-shield) head of known accuracy, from heating and cooling curves and from the velocity-observed temperature curve.

The accuracy of the original head has been determined in previous tests, (1) the "efficiences" obtained being shown in Table V. Thus in a case where an equivalent simple thermocouple would read 360 F (200 C) low at 1800 F (1000 C) the standard head with an efficiency of 97 per cent would read only 11 F (6 C) low.

TABLE V—EFFICIENCY OF ORIGINAL (2-SHIELD) HEAD

Temperature, deg C	1000	1300	1600
Efficiency (per cent) at 15 cu per ft per min flow	97	95	90

A comparison between observed readings with the modified and the original refractory heads is given in Fig. 11. The efficiencies of the thick heads have been estimated from these comparisons, the Super Selfrac head giving an efficiency of about 94 per cent at 2000 F (1100 C), dropping to 85 per cent at 2550 F (1400 C); and the zircon head, about 90 per cent at 1900 F (1050 C). These efficiencies were later verified during work on a chain-grate-stoker-fired furnace. The efficiency of the zircon head at the high temperature could not be reliably determined owing to difficulty in getting a comparative "no-suction" reading. The somewhat lower efficiencies of the zircon heads is to be expected owing to the higher thermal conductivity of this material.

Results are also given in Fig. 11 for a multi-shield extruded refractory head, developed by Land Pyrometers, Ltd., and the British Iron and Steel Research Association, which was fitted externally to the water-cooled jacket in a similar way to the other heads discussed in this paper.

The second method by which the pyrometer efficiency may be calculated utilizes heating and cooling curves. If, when the pyrometer is in the hot gases, the flow through the instrument is stopped, radiation is the only source of heat transfer and the pyrometer has the time constant τ_0. When the gas is being drawn through the pyrometer, both radiation and convection processes are involved and the pyrometer responds more rapidly with a different time-constant τ. It has been shown (3) that the ratio τ_0/τ may be related to the pyrometer

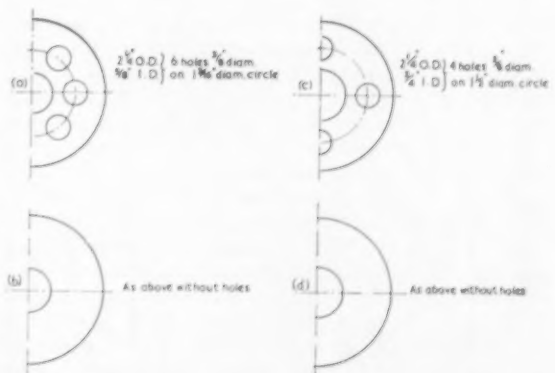


Fig. 9—Sectional drawing of heads in Table IV: (a) No. 1 in Table, (b) No. 2 in Table, (c) No. 3 in Table, (d) No. 4

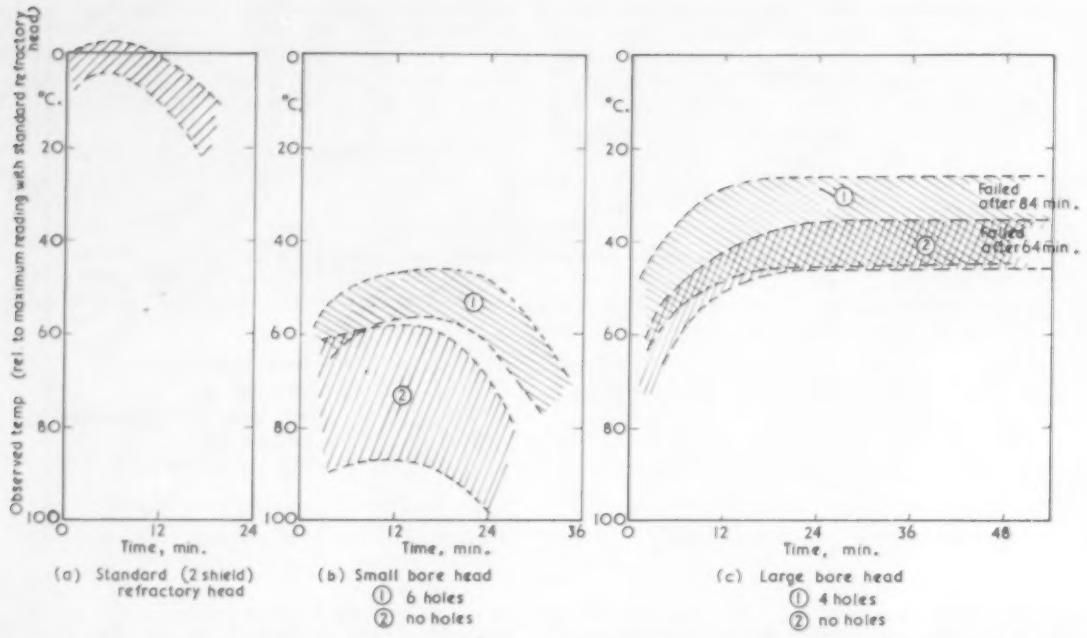


Fig. 10—Tests on the four heads of Fig. 9 above, show the effect of time on observed readings: (a) Standard 2-shield refractory head, (b) small-bore head with (1) 6 holes (2) no holes, (c) large-bore head with (1) 4 holes (2) no holes

efficiency. The relationship used is that calculated by Land and Barber for multi-shield systems and its application to the modified design can only be approximate, though any error will be small.

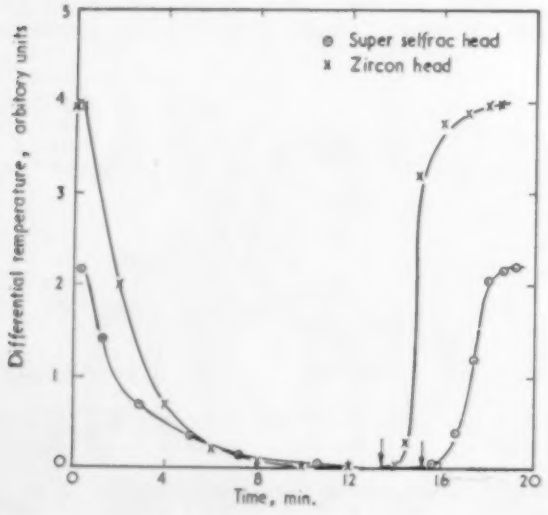
Typical heating and cooling curves for the modified heads are shown in Fig. 12 and, from these, the ratio of the time-constants can be calculated to be between 3 and 4. This corresponds to an efficiency of between 90 and 95 per cent, which is in reasonable agreement with that calculated by direct comparison.

Relative heating times for the original (2-shield) heads and the modified heads made from Super Selfrac and zircon brick are shown in Table VI. The rate of response of the modified head is about half that of the original head. A longer time is therefore needed for the readings to become steady after conditions have been changed, though readings can generally be taken faster than one every 5 minutes.

TABLE VI—RELATIVE RESPONSE TIMES FOR REFRACTORY HEADS

	Response Times, Min		
Approx. temp., Deg C (1850–200 F (1000–1200 C)	Original (2-shield) Head	Super Selfrac Head	Zircon Head
	2½	4½–5	4–4½

The change in the observed temperature with flow rate over the zircon head is shown in Fig. 13 and the



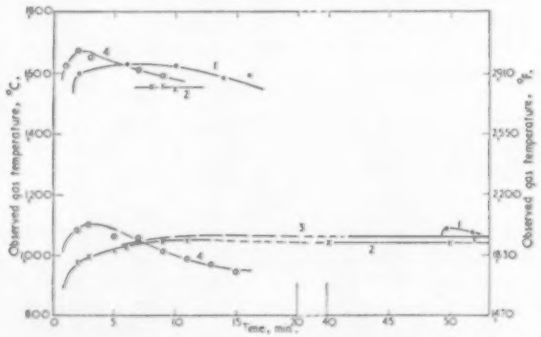


Fig. 11—Comparisons are made, above, between observed temperature and blockage rate: (1) 2-shield head, (2) zircon 4-hole head, (3) super-selfrac 4-hole head, (4) B.I.S.R.A.-Land head

←

Fig. 12—Typical heating and cooling curves, left, for 4-hole heads have arrow to show when suction was applied

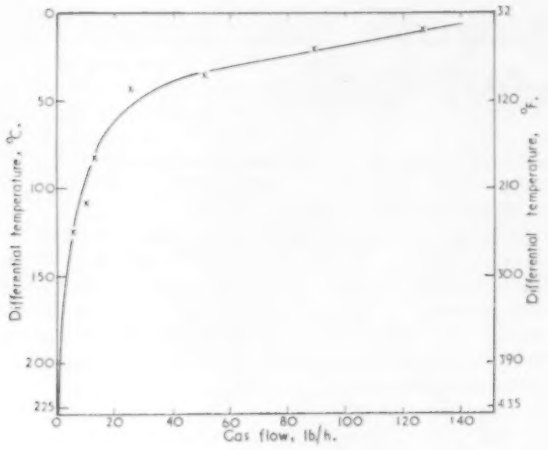


Fig. 13—Curve plots differences between gas flow temperature and observed reading with a zircon 4-hole head

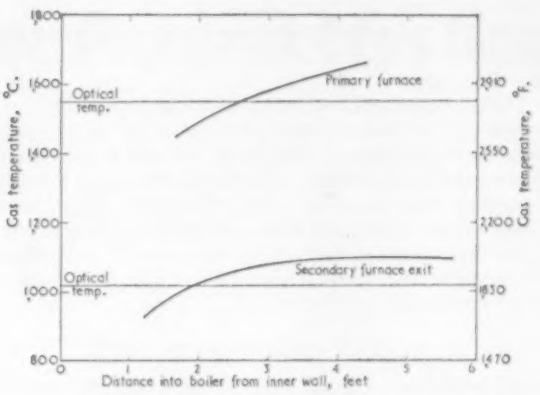


Fig. 14—Contrast shows between optical pyrometer and suction pyrometer on traverse for furnace temperatures

efficiency can, again, be estimated from this using a procedure developed by Land and Barber. A value of 93 per cent was obtained at a temperature of 1650 F (900 C) and a flow rate of 100 lb per hr. The gas velocity over the thermocouple at these conditions was about 275 ft per sec.

Summing up, the agreement between these various estimates of efficiency is reasonable and an efficiency for the zircon head of about 92 per cent at 1830 F (1000 C) can be accepted, compared with a figure of 94 per cent for the Super Selfrac head. The efficiencies of both heads will drop to the order of 85 per cent at 2550 F (1400 C) and probably to 75 per cent at 2750 F (1500 C).

Temperature Traverses in the P.f. Furnace

Temperature traverses were carried out in the boiler at the positions marked in Fig. 6 and the types of head used at these various positions are shown in Table VII. A very tentative picture of the temperature contours is also given in Fig. 6. It should, however, be noted that the traverses were made at right angles to this elevation.

TABLE VII—TEMPERATURE TRAVERSE DETAILS

	Position in Boiler	Type of Head Used	Notes
1.	Between primary and secondary superheaters	Metal	Very little dust blockage
2.	Between first tube bank and secondary superheaters	a. 2-Shield refractory head	a. Blocked rapdily with a fine orange colored powder
		b. Modified Super Selfrac head	b. Blocked after 90 min
3.	Just above burner level	a. Modified Super Selfrac head	a. No blockage during traverse or after 60 min
		b. 2-Shield refractory head	b. Two spot readings only possible, owing to blockage by "bird's nest" deposit

All the observed temperatures have been corrected, assuming the 2-shield refractory head to be 96 per cent efficient in the temperature range 1850–2550 F (1000–1400 C) and the efficiency of the modified head to be as given above. The efficiency of the metal head has been taken from the earlier work. These readings are of interest in showing the temperature variation in the furnace. The readings in the furnace just above the burner level are particularly interesting. It will be seen that the gases within 6 ft of the wall are fairly cool, the temperature rising rapidly 7 to 9 ft from the wall. It is suggested that the flame is almost entirely localized at this level in a core in the center of the furnace, owing to the vortex effect induced by the burners. As the flame rises, it tends to spread out, the maximum temperature being only some 4 ft from the wall at the superheaters. It would be interesting to examine this more fully, especially to see whether there is any dip in temperature in the center of the core.

It is also interesting to note that severe sintering on the heads occurred at temperatures of 2000 F (1100 C) some 300 F (170 C) or so below the ash-fusion temperature. There has been some criticism of the value of laboratory-determined ash-fusion temperatures in practice, and, where these temperatures are required to any accuracy, a determination *in situ* using a suction pyrometer or apparatus adapted from it is worth consideration.

Temperature Traverses in the Slag-Tap Furnace

The results of temperature traverses in the primary furnace and at the secondary furnace exit (points 1 and 2, respectively, in Fig. 7) are shown in Fig. 14. Traversing at both these points was limited by the cooling-water supply being insufficient to cool the probe fully. Temperatures measured with an optical pyrometer have also been included in Fig. 14. A comparison of these temperatures with those measured by the suction pyrometer shows that the optical-pyrometer is reading at least 110 F (60 C) lower than the maximum temperature recorded over the limited range traversed at the secondary furnace exit and about 180 F (100 C) lower in the primary furnace. This influence of the cold layer close to the wall on optical readings is generally observed, being more marked on pulverized-fuel flames owing to the opaqueness of the flame.

At the temperatures measured in the primary furnace the slag was molten and, on withdrawing the probe, set as the hard, black enamel-like coating shown in Fig. 1. Trouble with blockage during testing was actually less at these temperatures, though the cold deposits were almost impossible to remove. The major influence of the slag during testing was to raise the emissivity of the

shield surfaces so affecting their efficiency by an unknown amount. While the thick zircon heads can be used at these conditions it did not appear that their advantages outweighed the low accuracy; the increased heat flow by radiation overriding the effect of conductivity changes in the refractory.

The problems met with at these temperatures are very similar to those concerned with the waste gases from open-hearth furnaces, and methods devised in this latter case should be applicable to the slag-tap and wet-bottom pulverized-fuel furnaces. Other methods than those based on the suction pyrometer are probably most promising; for example, direct measurements of total heat, "pneumatic" pyrometry, etc. Some work along these lines is proceeding at B.C.U.R.A.

Conclusions

While the use of the suction pyrometer in pulverized-fuel flames and similar gases with a high dust concentration is appreciably more difficult than with clean gases, an instrument of suitable design can be used successfully. No serious trouble is likely to be experienced at temperatures below about 1850 F (1000 C), since the dust mostly passes through the instrument; but as temperatures are reached at which the dust starts to become sticky, bulky deposits form both on and in the heads.

It is recommended that in the temperature band where these deposits form, i.e., 1850 to 2750 F (1000 to 1500 C), the design of head illustrated in Fig. 9-c be used. This is robust, easy to clean and can be used for periods of the order of an hour before the efficiency starts to change owing to the presence of the deposit. The "efficiency" of this design of head, made either from Super Selfrac or from zircon, has been estimated by various methods. The efficiency of the zircon head at 1850 F (1000 C) is about 92 per cent, falling to about 85 per cent at 2550 F (1400 C). This means that, on a typical boiler where the recorded temperature without suction (i.e., the reading given by an equivalent sheathed thermocouple) is probably 300 F (167 C) low, the zircon head will read 24 F (13 C) low at 1850 F (1000 C), falling to about 45 F (25 C) low at 2550 F (1400 C).

Sampling at temperatures above 2750 F (1500 C) when the ash is molten is only of limited interest in pulverized-fuel flames. At these temperatures it is probably best to use orthodox multi-shield heads, replacing the head after each spot reading. Methods other than suction pyrometry may be more convenient at these conditions.

Acknowledgments

The authors would like to thank C. K. Branthwaite, Station Superintendent, Croydon "B" generating station and G. E. C. Attwood, Station Superintendent, Stourport generating station, and their staff for help and cooperation. They are grateful also to Dr. R. Jackson, Superintendent, Physics Department, British Coal Utilization Research Association, for his advice throughout these tests. Permission to publish this paper has been given by the Director General of the Association.

BIBLIOGRAPHY

(1) Barber R., et al., *J. Inst. Fuel*, **27**, 408 (1954).
(2) Marskell, W. G., and Pratt, C. W., *ibid.*, **25**, 212 (1952-1953).
(3) Land, T., and Barber, R., *Trans. Inst. Instrum. Tech.*, 6, 112 (1954).

Lack of Patent Examiners Called Serious Problem

American industry is facing long delays in obtaining patent coverage for products and processes otherwise ready for the market, according to reports made at a recent meeting of The New York Patent Law Association by the Commissioner of Patents.

These delays stem from the great increase in the number of patent applications filed during the past few years. This flood of inventions has stretched the average prosecution time per patent to three and a half years.

The association points out that the Patent Examiner thus holds a key position in the advancement of American technology and that the only way to reduce these delays and clear the way for marketing the new products and processes is to employ new Patent Examiners to pass upon the backlog of applications which is piling up in almost every technical field.

Steps have already been taken in this direction and approximately 100 new Patent Examiners have been added to the examining staff since last June. It is understood that the Patent Office wants 300 new Patent Examiners in 1956; 125 in the first quarter, 25 in the second quarter, and 75 in each of the last two quarters. There are immediate openings for engineers and scientists who can accept appointments in Washington now.

Patent Examiners pass upon applications for patents in a wide range of technical fields to determine whether they are novel and whether invention is involved. This calls for a study of the issued patents and the related scientific literature. The Association points out that the technical graduates who apply will find the job both interesting and stimulating and one which keeps them in close touch with the latest technical developments. The job offers opportunities for rapid advancement within the Patent Office. Washington also offers unusual opportunities to carry on graduate studies.

Salaries for Examiners start at $4,345 a year, and it is possible to reach a salary of $7,570 in five and one half years, with salaries in excess of $13,000 available. The Patent Office also offers liberal vacations and sick leave and pension benefits.

Engineers and scientists holding a college degree in engineering or applied science, or a degree with a major in chemistry or physics, or with certain combined credits in these fields, are eligible for appointment as Patent Examiners, without examination, upon application to the Commissioner of Patents in Washington, D. C.

While Congress has appropriated additional funds for these new Patent Examiners the existing demand for engineers and scientists in industry makes it almost impossible to obtain enough candidates having the necessary technical qualifications. Because this is becoming a matter of national concern several of the patent law associations have agreed to supplement the work of the Patent Office in recruiting new Examiners.

Diversified Program at AIEE Winter General Meeting

WITH more than 5000 engineers registered during the week of January 30–February 3, the American Institute of Electrical Engineers held its largest and most successful Winter General Meeting at the Hotel Statler in New York City. More than 500 technical papers and reports were presented in the broad fields of communications, general applications, power, engineering science and electronics.

In commemorating the 250th anniversary of the birth of Benjamin Franklin, **Morris D. Hooven,** president of the AIEE, contrasted today's art of electrical engineering with that at the time of Franklin. Mr. Hooven, who is an engineering executive of Public Service Electric & Gas Co., then painted a picture of the home that will be possible within the next few years. Made up of solar batteries, heat pumps, weather conditioning, skillful illumination, refrigeration and cooling devices, labor saving and chore-doing equipment, and comfort-producing gadgets, the home still needs an operator, and Mr. Hooven suggested that automated electronic devices may be the means of relieving the family of much of their tension and worry.

The keynote address at the meeting was delivered by **Roger M. Blough,** chairman of the Board of United States Steel Corp. Mr. Blough expressed the belief that the present shortage of engineers and scientists in the United States is due primarily to the unprecedented growth of our economy rather than the threats imposed by Russian advances in technology, though he warned that we should not underestimate the Soviet advances and potential for harm from the use of technological skills that lack the checkrein of political restraint and high human standards. The United States is now moving toward solution of the technical manpower problem "within the tested American process of responsible persons doing their own thinking and acting in a competitive economy" in three ways: (1) through operation of the law of supply and demand to increase the financial reward of engineering careers, (2) through better utilization of engineers in industry by increased use of electronic machines and engineering aids to minimize routine work performed by engineers, and (3) through appealing to young people to join the engineering profession on the basis of the honor, prestige and sense of service in such careers. The last point was elaborated upon in the concluding phases of Mr. Blough's inspiring address, sections from which were quoted on page 33 of February COMBUSTION in an editorial entitled "Where Now in Engineering Manpower?"

Honorary membership in the AIEE was awarded to **James F. Fairman,** vice president of Consolidated Edison Co. of New York. In accepting this honor, Mr. Fairman made a plea for unity of the engineering profession, urging that time not be wasted debating objectives or the meaning of unity, but that efforts be devoted to getting at the obvious day-to-day problems. He stressed the desirability of working harder at the grass roots in order to lay a better foundation for unity at the national level.

The Edison Medal was presented to **L. A. Umansky** of the General Electric Co. for his outstanding contribution to the electrification of industry through the application of electrical machines, devices and systems to automatic process machinery, and for his inspiration, leadership and teaching of men in this work.

Mervin S. Coover, head of the Electrical Engineering Department of Iowa State University, Ames, Iowa, was nominated for the 1956–57 presidency of the AIEE.

Attracting Young Engineers

The electrical utility industry was warned that unless it devises means of attracting graduating student engineers to the power industry, it soon will find that it is getting only the "dregs"—men who couldn't locate a job elsewhere.

The warning was sounded by **Prof. J. S. Johnson,** head of the School of Electrical Engineering, Purdue University, who stated that the electric utilities are lagging far behind in attracting the services of enough good engineers. They are getting some recent college graduates and a few of them are good men. By and large, however, they have not gotten the best men by any means. Many of the utilities are concerned about this. However, over the country there are utility personnel who are emulating the ostrich and hiding their heads in the sand saying, "It's just a cycle. It will change." It will not change short of a major recession unless steps are taken to do something about it.

At the present time, except for foreign students, only a small minority of graduating electrical engineers are interested in power. Professor Johnson said that the electric utility is not presenting the industry colorfully, but in prosaic black and white, and he suggested, among other things, glamorizing the power industry so as to attract students; upgrading of wages for utility engineers; more challenging problems for the young engineer; hiring of electrical engineering professors as utility consultants so they can become more familiar with utility problems; inauguration of research projects by utilities and training periods for young engineers just entering the utility field.

The whole issue turns on one point, however—the stimulation of students in the power field. Granted, there will always be a few good men who are interested in or enthusiastic about the power utility, but those are not going to be nearly enough to man the electric utility of the future. Many companies have not yet felt this pinch—numbers possibly, but not necessarily quality. Or if they have, they may have attributed it to the national shortage of engineers. But it is obvious to anyone who has been in a position to observe at first hand the swing in student interest away from power, that the shortage of engineers is not the sole or primary cause.

The power industry is one of the most vital parts of our industrial America. The possibility of its being unable to perform its function adequately in years to come, lacking the best personnel available and the most

highly developed equipment possible, is a matter for deep concern.

According to **J. D. Ryder,** Dean of Engineering at Michigan State University, utilities have recently failed to realize that in a buyer's market one must cultivate the customers and keep one's name before them. They are not doing this on the college campuses. When as many as ten companies are interviewing students on a given day it is obvious that a student cannot see all. He picks the companies whose names and products are known to him or to his professors who have much influence at this point. Enlightened companies call on the campus regularly, year after year, at interviewing time and at other times, so that their names appear regularly, so that the faculty are aware of the companies' products and policies, and can wholeheartedly commend the students to spending time in an interview. Utilities too often tend to go to the well only when the pitcher is empty.

Professor Ryder recommended that utilities, in order to get the better grade graduate, take a look at their pay scale, make their work more interesting and creative, and institute research programs. Until such programs of fundamental work, divorced from day-to-day operation and planning, are undertaken in the utilities it seems unreasonable to expect a reversal in the trend of the young engineer away from the electric utilities, a shift which has already taken place with respect to another utility, the railroads.

Graduates are being oriented more and more toward the engineering of the future, toward the day when all engineering will be creative, and less highly trained people or the computer will take over the routine. With the young engineer so directed, it is apparent that unless an industry can offer creative opportunity it must be satisfied with only repetitive mediocrity.

In contrast to the foregoing, the electric utility business offers young graduate engineers excellent opportunities, according to **Murray Joslin,** vice-president of the Commonwealth Edison Co., Chicago. To the young man about to graduate from an engineering school, he added, these are points about our company in which I firmly believe: For the engineer who wishes to make a career in strictly engineering work, the electrical utility business, facing new technical problems each year, offers very satisfying opportunities; non-engineering management positions afford promising opportunities, and these are also open to engineers; both the number and the wide range of opportunities result in making this electrical utility business a good place in which to seek a career.

Some of us believe that we can, over a period of years, arrange to do a larger amount of work and do it better with fewer engineers than we now employ, he said. Such an objective is certainly in the national interest. It should result in raising engineering morale through improvement in the professional status of the engineers we do employ.

His company, he continued, is tackling the problem of engineers by streamlining its engineering organization and its procedures, by standardizing to avoid re-engineering repetitive jobs, by increasing the use of non-graduate technical aides, and by the use of computers and similar devices.

Batteries and Fuel Cells

In a paper entitled "Nuclear Batteries," **William Shorr** of Signal Corps Engineering Laboratories, Fort Monmouth, N. J., stated that it is not believed that the widely used chemical battery will ever be seriously challenged by the nuclear battery. The minute amount of power (of the order of microwatts presently available from the nuclear battery) will limit its application to those areas where the intrinsic characteristics of the nuclear device would be used to most advantage. With the further development, however, of more effective radiation shielding materials (which would enable the use of greater source activity) and greater improvement in the conversation efficiency of radiation energy to electrical energy, it may be possible to broaden the power output range by a magnitude or more. The characteristics of special significance in the nuclear battery are:

a. A source of continual voltage and current in a compact and portable size.

b. Very long life, generally considered equivalent to the half-life of the radioisotope employed.

c. Operation inherently insensitive to extreme temperature conditions, pressure variations or strong electric or magnetic fields.

The concept of the nuclear battery is not new; as early as 1913 H. J. G. Moseley described a nuclear charger with which he achieved voltages of over 150 kv. The significance of the nuclear battery, as a practical device, had to await the development of the nuclear reactor and the subsequent availability of large quantities of fission-products and pile-activated radioactive isotopes at relatively low cost.

The source of energy in the nuclear battery is the radioactive isotope. As the isotope undergoes spontaneous disintegration, the strength of the source is reduced accordingly; the rate of change being characteristic of the isotope. Thus the useful life of the nuclear battery is limited only by the half-life of the isotope and the specified electric power output. The half-lives of the known isotopes vary from fractions of a second to about 10^{12} years.

Frederich Kornfell of the Signal Corps Engineering Laboratory, Fort Monmouth, N. J., presented a paper entitled "Fuel Cells." Since most primary cells used in practice involve the use of metals as anode material and since a considerable amount of energy is required to produce that metal in the first place, the net efficiency of the production of electricity from a primary galvanic system is low. It is desirable, therefore, to have a galvanic cell in which the material serving as anode is one of the substances used as fuels, i.e., essentially carbon or—with only small losses of energy—carbonaceous fuels. The cathodic material in such a cell would normally be atmospheric oxygen. The chemical reaction is the combination of carbon and oxygen to form carbon dioxide or carbon monoxide; thus, the cell reaction is essentially the same as the one occurring in the combustion of fuels, but, in principle, the efficiency of the process should be much greater than when electrical energy is produced by

a process involving thermal combustion and a heat engine. Cells of this type are called fuel cells.

The underlying principle for all types of fuel cells is to supply oxygen to the fuel in an ionized condition so that a potential difference is produced and an electric current is obtainable. That the idea still awaits practical fulfillment today, is most likely due to the limited scale on which the experiments were made, to a lack of fundamental knowledge of the kinetics of the cell reactions, and to the fact that a reaction which can be summarized by the equation:

$$C + O_2 = CO_2$$

actually takes place in several stages, one or more of which may not be reversible in the strict thermodynamic sense.

The numerous fuel cells reported in the literature may be divided roughly into two classes: *direct* fuel cells, in which carbonaceous material forms the attackable electrode, and *indirect* fuel cells, in which gaseous fuels such as carbon monoxide and hydrogen are used to saturate the negative electrode. Other types of cells have been devised employing an electrode of a metal which has been reduced by the fuel, but the conversion of the fuel energy to electrical energy is also indirect and considerable energy losses result from the preparation of the electrode; the additional operations also make the process uneconomic.

The main problem concerning the low temperature fuel cell is the slow rate of the electrode reaction. The difficulty of slow rate of reaction had to be overcome in the field of high pressure catalysis and has been solved there. It may, in time, also be solved here. Actually, an increase in current density by a factor of 5 to 10 over the present-day fuel cells would be sufficient to arouse a strong technical interest.

According to **A. M. Adams** of Central Electricity Research Laboratories, Leatherhead, England, who presented a paper entitled "Electrochemical Cells As Energy Converters," interest at present appears to be concentrated on three types of cell: redox, hydrogen, and high temperature gas cells. Redox and hydrogen cells employ aqueous solutions as electrolytes but at high temperatures fused or solid electrolytes must be used.

Certain constructional features are common to many different types of cell. For instance, porous disc or plate electrodes are most often used. If the electrolyte is a liquid, it is normally circulated, to reduce concentration polarization. Gaseous reactants are introduced at the rear of their respective electrodes and reach the electrolyte interface by mechanisms not fully understood. An alternative tubular form of construction has sometimes been adopted, particularly for high temperature gas cells with rigid electrolytes; this has the advantage that gas-tight seals need not be made in the high temperature zone, but good contact between the electrodes and electrolyte may be more difficult to achieve with this arrangement.

Redox cells have the potential advantage of operation directly on a carbonaceous or hydrocarbon fuel, since this does not enter the cell itself. The principle depends on the alternate reduction and oxidation of an ion capable of existing in two valency states and can be illustrated by a simple system based on the ferrous-ferric equilibrium. Two inert electrodes (e.g. platinum or carbon) are immersed respectively in solutions containing ferrous and ferric ions and a common anion (e.g. chloride or sulfate). The two solutions are prevented from diffusing into each other by means of a diaphragm permeable to hydrogen and hydroxyl ions but not to the ferrous or ferric ions. Initially such a system would provide a potential difference of about 0.25 v between the electrodes, which would decay to zero if the electrodes were externally connected so that electrons could flow from one electrode to the other. At zero potential difference, the ration of ferrous to ferric ions in the two solutions would be equal. But by circulating the ferrous solution through a regenerating apparatus, any ferric ions produced owing to loss of electrons to the electrode could be reduced back to the ferrous state by reaction with the fuel.

Similarly, ferrous ions could be oxidized back to the ferric state by reaction with atmospheric oxygen in the presence of suitable catalysts. By these regeneration processes, which can be carried out independently under the most suitable conditions, the initial concentration of ferrous and ferric ions could be maintained, in spite of current being drawn from the cell, while the overall reaction would be

$$C + O_2 = CO_2$$

Hydrogen cells represent the only type of direct cell that has been successfully operated at atmospheric temperatures. In principle, the system consists merely of a hydrogen and an oxygen electrode immersed in a suitable aqueous electrolyte. To attain reasonable current densities without polarization at low temperatures, it is necessary to use materials with highly developed surfaces for the gas electrodes and it is generally considered that such reactive materials would be easily contaminated by the presence of impurities in either the hydrogen or oxygen supplies. Further, recent investigators have favored caustic alkali electrolytes, which form carbonates and formates respectively, with carbon dioxide and monoxide. Both these gases are possible impurities in hydrogen prepared from coal or coke, while carbon dioxide is present in appreciable concentration in air. There is some evidence that carbon dioxide at least produces no rapid deterioration of the electrolyte, but it must result in some reduction of its effectiveness.

A hydrogen-oxygen cell operating at 200–240 C with an aqueous potassium-hydroxide electrolyte, at a pressure of 400–800 lb per sq in, has been developed by F. T. Bacon and his associates at Cambridge, England, with the support of the British Electrical Research Association and Ministry of Fuel and Power. In this cell, porous sintered nickel electrodes, operating on diffusion principles, are used. By arranging for a small pressure differential to exist between the gas and electrolyte faces of each electrode, some electrolyte enters the pores of the electrodes, but not sufficient to flood them completely. No diaphragms or water repellent films, which inevitably increase the internal resistance of cells in which they are employed, are necessary and probably a large part of the internal surface of the electrodes is available for reaction. The internal resistance is also kept low by placing the electrodes close together and the electrolyte is circulated by a thermal syphon. The high pressure

and the increase in temperature in conjunction with the large effective electrode area, result in low activation polarization, so that current densities as high as 1000 amp per sq ft have been attained. Some initial difficulties due to deterioration of the oxygen electrode now appear to have been overcome and cells have been operated on load for several weeks at temperatures and current densities somewhat below the figures mentioned.

The third type of cell operates at high temperatures, the object being to accelerate the desired reaction and to reduce activation energy barriers. In practice, it is possible to operate many varieties of cell in the 500–600 C range, but difficulties arise, chiefly associated with the electrolyte, owing to the tendency of fused salts to attack the electrodes and constructional materials and for side reactions to occur. It has been claimed that many of these disadvantages can be overcome by using so-called solid electrolytes. An important advantage of the solid electrolyte is that it would facilitate series connection of cells. It now appears to be generally accepted that these solid electrolytes are not true solids, under operating conditions. To be of any value as an electrolyte, conduction must be by means of ions and although many ionic solids show appreciable conductivity at temperatures considerably below their melting point, this is generally owing to the mobility of electrons, due to a semi-conductor mechanism, rather than of ions. All these electrolytes might be termed mixed phase electrolytes. Ideally, it would be desirable to use a pure ionic oxide as the fused electrolyte, but owing to the difficulty of finding such a substance with a low melting point, recent investigators have used carbonates instead of oxides. The electrodes employed in conjunction with these electrolytes are usually metal oxides, such as iron and copper oxides; silver and nickel have also been used.

Solar Energy

"Solar Energy, A Supplemental Energy Source" was the subject of a paper by **Henry B. Sargent,** president, American and Foreign Power Co. It is quite certain that in fifty years we will have found ways to utilize atomic energy economically and practically in large cities or even in medium-sized cities. But even then there will still be many areas of low energy demand density where solar energy can have a techno-economic advantage. House heating is a good example. Today we heat houses with coal, with oil, with gas, or even with electricity. Even if atomic energy becomes competitive with that from conventional sources, it is probable that solar energy will become the fuel for space heating, once coal, gas, or petroleum costs have skyrocketed. There is no doubt also that in rural locations, in areas where energy demand is very diffuse, it may be economically preferable to exploit solar energy at the point of consumption rather than support the high transmission costs from a central nuclear power source. There is no need to remind this audience that no matter how cheap nuclear fuel may make the *generation* of electricity it will have little effect on the cost of transmission and *distribution* of that electricity.

The main drawback to solar energy until now has been the high cost of the equipment required to use it and the intermittent supply of this resource. Research centers the world over are looking for a cheap way to store energy, and widespread use of solar energy will greatly depend on our ability to develop this storage device. Once we can store energy cheaply and efficiently, the major problem of using solar energy will have been solved. Then it may be possible to store heat during the summer for use during the winter, and perhaps it will even be possible to store cold during the winter to increase cooling comfort during the summer.

Solar energy will best be used in the future in conjunction with other energy resources like atomic energy. Solar energy will complement atomic energy in helping supply the world energy demand. It will be used where the density of energy demand is low as is appropriate to an energy source which is diffuse but omnipresent. It is also doubtful that solar energy will be used to any extent in the crowded city, but it is probable that solar energy will find very heavy uses in suburban, rural, and isolated locations. It is extremely possible that the sun directly will satisfy as much as 30 to 40 per cent of the world's energy requirements in 2050.

Steam Turbine-Generators

"The Design and Performance of Modern Large Turbine-Generators" was the title of a paper by **B. M. Cain** and **Dean Harrington** of General Electric Co. New developments in the design and manufacture of large turbine generators have given the designer a new versatility for meeting the user's needs. This paper is concerned with the complex interworking of numerous technical and economic relationships which influence specific design choices. Conventional machines, and those having each of the many possible combinations of conductor-cooling arrangements, all have different characteristics of economic and performance relationships. The paper shows the unique aspects of conductor cooling, which are brought about because machine size is limited primarily by economic considerations rather than by temperature.

The many design choices include conventional ventilation as well as the several varieties of conductor cooling. The physical laws of each of the methods of cooling affect the performance characteristics of the machine. Although individual designs will show important differences, patterns of design trends are demonstrated for conventionally cooled machines as one class and for conductor-cooled machines as another. The paper shows how the designs of conventional machines are determined primarily by temperature limitations, while those of conductor-cooled machines are determined primarily by other considerations such as the economics of size and efficiency. Instead of being limited by temperature, the conductor-cooled design has a ventilation system adjusted to provide the conductor temperature required.

In a conductor-cooled design of a given specific capacity, lowest total losses are obtained by designing the ventilation system for maximum permissible conductor temperatures. Hence, conductor-cooled machines are designed to have the same maximum conductor total temperature as conventional machines.

The choice of gas pressure for conductor-cooled designs depends on a balance of performance requirements,

simplicity of design, and economics. High gas pressure simplifies the design of the fan or compressor for gas-conductor-cooled windings, but its use may reduce efficiency. Capability in air may have to be reduced to zero when gas pressures as high as 60 psig are used. When provision is made for operation in air or at low hydrogen pressure, efficiency levels at rated output are slightly reduced.

The required short-circuit ratio has an important effect on generator size and efficiency. Higher short-circuit ratio means larger physical size or lower efficiency, or both, for otherwise comparable performance. However, possible reductions in size to be gained from reductions in short-circuit ratio below currently accepted levels are small compared with reductions in size to be gained from conductor cooling.

The area of practical designs of conductor-cooled generators tends to encompass loss levels higher than for conventional designs. However, conductor-cooled generators can be designed with losses approaching those of conventional machines of comparable rating but in general will have to be larger than designs which utilize the full possibilities of improved cooling techniques.

In a paper entitled "Liquid Cooling of Turbine Generator Armature Windings," **C. E. Kilbourne** and **C. H. Holley** of the General Electric Co., pointed out that liquid cooling is basically not a new idea. A study of the patent literature shows that many people in Europe and the United States have, over quite a few years, recognized the merits of this approach. The company with which the authors are associated applied liquid cooling to the armature core of a turbine-generator in 1937. The first turbine-generator, a 260,000-kva, 3600-rpm, 18,000-v machine with liquid cooled armature windings, was completed and tested in 1955 and is to be placed in operation at the East Lake Station of the Cleveland Electric Illuminating Co., early this year.

Liquid cooling is a practical and effective tool to increase the outputs attainable from turbine-generator armature windings. The liquid coolant system, now perfected, can be applied readily to all sizes and types of large machines without involving complex design proportioning to accommodate the cooling system. Basically this is so since the cooling ability provided by the liquid cooled approach establishes a thermal limit for the armature winding much higher than other design limitations in the completed machine. Consequently, with liquid cooling thermal design of the armature winding is no longer a limiting factor. The circulating system is extremely simple and very reliable. This step parallels in many respects the step to hydrogen cooling made some 20 years ago when a more effective heat-absorbing fluid than the air previously used was introduced into the machine.

The thermal limit of liquid-cooled windings easily permits the design of armatures for 500,000-kva rating in 3600-rpm machines, and undoubtedly larger capacities are possible. However, other limitations in the complete machine design are likely to be lower than this figure. Nevertheless, today 3600-rpm generators are available in capacities of 400,000-kva or more at 30-psig hydrogen pressure. Such ratings are practical within the weight and dimension limitations set by American rail transportation, and the mechanical limitations of stress and critical speed established by the rotor diameter and length. Even larger kva 1800-rpm generators are practical, and the combination of two such generators in a cross-compound turbine-generator unit brings into focus a very real possibility of generators feasible for a 1,000,000-kva unit.

Today over 2,000,000-kva of large 3600-rpm generators, ranging in capacity from 200,000-kva upwards, and having liquid-cooled armature windings, are under construction. These are the forerunners of many similar generators in the future.

"Operation and Maintenance of Hydrogen Systems for Turbine-Generators" was the subject of a paper by **S. C. Barton** and **W. H. M. Olson.** Two types of hydrogen systems are used with turbine-generators by the General Electric Co. These are commonly referred as the vacuum and continuous scavenging systems. The basic principle of operation is the same for both systems; they differ only in the treatment of the oil supplied to the seals and the manner in which hydrogen is maintained at proper purity values in the generator casing.

The heart of the hydrogen system is the shaft seal which prevents leakage of hydrogen from the generator casing along the shaft. Each seal presently consists of a pair of segmented rings contained in a seal housing. The rings are held together radially and apart axially by two coil springs attached to the housing. These rings fit with close clearances around the shaft. They are free to expand radially but are fixed from rotating by a pin which projects from the housing. The oil which is supplied to the housing at a pressure higher than the hydrogen pressure in the generator, flows between the rings and then both ways along the shaft through the annular clearances between the rings and the shaft—thus forming the seal.

With the vacuum system, vacuum treated oil is supplied to the shaft seals. This results in negligible amounts of air or moisture being released in the generator by the oil that passes through the small annular clearance between the seal rings and the shaft and discharges to the hydrogen side of the seal. The quantity of oil supplied to the seals is critical only in so far as pump capacity and pumping of power is concerned. The seal rings are designed with the clearances between the rings and the shaft proportioned to give a low total flow of oil through the seal to the air and hydrogen sides.

Because of the low air and moisture content of the sealing oil, the degree of contamination of the hydrogen near the shaft seals is very low. Proper hydrogen purity in the generator is automatically maintained by the introduction of fresh hydrogen to replace that lost by normal frame leakage and that lost by absorption to the oil. Under normal operating conditions, the hydrogen purity is maintained at a value of 98 to 99 per cent.

The vacuum system was the first hydrogen system developed and has been applied to generators rated 15,000 kw and above. Since the development of the scavenging system, which is somewhat simpler, the vacuum system has been normally applied only to generators having shaft journal diameters of 14 in. or larger (147,059 kva and above).

With the scavenging system, untreated oil containing

some dissolved or entrained air is supplied to the seals. Appreciable amounts of air are released by the oil that passes to the hydrogen side of the shaft seal into a seal chamber located between the seal rings and an inside oil deflector. The amount of impurities introduced into the generator with this sytem is a direct function of the oil flow to the hydrogen side of the seal rings. The seals are designed to fit with close radial clearances around the shaft such that a very small amount of oil flows to the hydrogen side of the seals while the air side flow is large enough to provide sufficient cooling for both rings and thus limit the radial expansion.

By continually scavenging a small amount of the gas from the seal chamber, such that a small flow of hydrogen is established through the oil deflector clearances, the air released from the untreated oil is removed. Proper hydrogen purity is maintained by the introduction of fresh hydrogen into the casing to replace the scavenged gas and that lost due to normal frame leakage. The scavenging rate is regulated so that the hydrogen purity in the casing is maintained at a value between 96 and 98 per cent.

This system is presently applied to 3600-rpm units up to and including those with 13-in. diam shaft journals (or about 133,689-kva rating). For 1800-rpm units, the system has been extended to include units up to 19-in. diam shaft journals (or about 156,250 kva).

Hospital Power

"Emergency Power for Hospitals" was the topic of a paper by **N. L. Griffin,** U. S. Public Health Service, Washington, D. C. The concept of emergency service for hospitals has changed considerably during the past few years and has progressed along with working and living habits to which people become accustomed. Various ideas on the extent and method of applying emergency power have been incorporated into hospital designs. A few years ago it was common practice to provide only a small amount of emergency lighting for use during expected minor interruptions of the normal utility service. Today's planning usually provides for more extensive emergency lighting and also for operation of certain equipment. In addition to a minimum of emergency lighting and an increasing use of electrically operated devices in the treatment of patients, there are other outstanding reasons for favorably considering a more generous amount of power. It is conceivable that enemy action could seriously interrupt utility service so that hospitals in the area might be without normal electric service for several days. Any such act of violence or major disaster is expected to be followed by many casualties and may result in the need for all available hospital facilities.

In regard to the adequacy of an emergency power system two extremes must be considered. For hospitals located in a mild climate far from industrial centers and otherwise protected so that only the usual run of power outages of short duration are expected, the minimum amount of emergency power for specific lighting only might be considered adequate. On the other hand, if the hospital were located in or serving a heavily industrialized area and also within or serving a target area, the maximum amount of emergency power might be desirable. The maximum amount of emergency power would be that sufficient for functioning of all facilities of the hospital. Except for strategic military hospitals, justification for maximum emergency power would be extremely rare. The cost involved in providing emergency power facilities is an important consideration.

The three sources of power considered as acceptable for hospital emergency systems are storage batteries, generators, and a second utility line.

Where only one source of emergency power is to be provided, generators are preferable to storage batteries because of the capacity limitation of a storage battery and the need for operation of a-c motorized equipment for which the batteries are not directly suitable.

In many cases a second utility line leading to the hospital over a route remote from the first line and energized from a separate generating plant is acceptable as an emergency source of power. These lines may be interconnected if protected against a local disturbance so that a failure on one line will not cause a failure on the other line.

For dependable service, storage batteries as well as generator prime movers must be regularly serviced and adequately maintained. Even with maintenance as good as may be expected in the average hospital, there is a possibility that an internal combustion engine may fail to start automatically. While service from two utility lines is generally more dependable than the automatic starting of a generator, there is the possibility of disasters or storms great enough to cause an extended interruption of service from both utility lines. An automatic generating unit which has failed to start automatically can usually be started manually within a reasonably short time.

There should be no appreciable interruption of lighting in operating and delivery rooms. Batteries are capable of supplying lighting immediately but they can supply energy for only a limited time. Generating units are not so limited as to the length of time they can supply energy but they require more time for starting to supply energy. The period of time required for generator starting is usually only a few seconds. However, that time might be too long if it occurred in the midst of a critical surgical procedure.

Experimental Boiling Water Reactor

The General Electric Co. and the Pacific Gas and Electric Co. notified chairman Lewis L. Strauss of the Atomic Commission on March 1 of their decision to build and operate a 5000-kw atomic power plant to serve the San Francisco Bay area. The plant, which will be located in the Livermore-Pleasanton area of Alameda county, Calif., will be financed entirely by private capital. Plans call for completion of the plant during 1957 at a cost of between $3,000,000 and $4,000,000.

The General Electric and Pacific Gas and Electric Co. plant will use a nuclear reactor of the boiling water type. The experimental reactor facility will be constructed and operated at the General Electric Co.'s new atomic laboratory near Livermore. The reactor is a pilot plant for the 180,000-kw station to be built near Chicago by G.E. for the Commonwealth Edison Co., which is associated in this project with the Nuclear Power Group, Inc. As part of the development of the dual-cycle reactor concept, it marks a major advance toward economically competitive electricity from nuclear fuel.

It Takes More Than Fire and Water to Make Steam

By GREGORY GOULD

Secretary-Treasurer,
Fuel Engineering Co. of N. Y.

Few plant managers would be so bold as to declare that their power plants are above the need for close scrutiny of their fuel procurement and utilization activities, because these activities contribute so significantly to the economy and facility of operation. The specialized knowledge required and the inherent difficulty of avoiding any influence from divergent operating and purchasing interests places a premium on the objective approach of the independent consultant. In its nearly fifty-years accumulated service, the author's company has developed a variety of solutions to problems encountered in these aspects of steam generation. He has selected several actual cases to illustrate the scope and complexity of common situations which arise. You may find that similar possibilities exist in your plant.

HERE is a classical example of how dramatic savings are brought about by taking full advantage of the tolerance limitations of a plant's equipment and making more effective use of the facilities at hand. The client involved was a large mid-west manufacturing concern whose coal-fired boiler plant was being operated at good efficiency levels as disclosed by a thorough field investigation. And yet the fullest measure of economy was not being realized. Significantly, this type of problem does not advertise itself and the means for achieving the maximum economy potential may seem at first to contradict known facts.

Picture, if you will, a plant with five boilers consuming 40,000 tons of coal per year that represented a total installed capacity of 375,000 lb per hr. In summer, the steam load was 60,000 to 70,000 lb per hr; generally carried by two 67,500 lb per hr units. In winter, the load averaged 200,000 lb per hr and was normally carried on their larger 150,000 lb per hr unit together with a 67,500 lb per hr boiler. The existing schedule for distributing the load on two boilers summer and winter resulted in operation at or near capacity in the winter time and was conducive to continuously maintaining high levels of efficiency. Why then should this plant not be securing the best economy?

Coal Procurement

Examination of coal procurement showed that the client was obtaining competitive market prices for the coals they were using. Samples were taken, and tested in the laboratory, of several coals currently in use and in storage. On the basis of a weighted average of their heating values and their delivered costs, these coals represented an average energy cost of 26.5 cents per million Btu. At the time of our investigation, the better energy values among the coals available to the client would deliver for an average cost of 24.5 cents per million Btu. This difference is equivalent to 50 cents per ton and indicated that savings on the order of $20,000 were possible.

An analysis of furnace conditions under usual loads revealed that the ash softening temperature (AST) characteristic of the better market values available to the client could not be accommodated. Other coal characteristics—grindability, volatile content, and sulfur percentage—were found to present no problem or restriction in regard to efficient trouble-free operation. The pulverizing mills in the plant could handle even the hardest-to-grind coals; most of the mining areas that ship into the client's location produce high volatile coals; and normal air heater exit temperatures of the plant allowed the use of coals up to 3 per cent sulfur.

Factors in Addition to Efficiency

The importance of efficiency on economy of operation cannot be denied; but there are several other factors which also have a telling effect. When you find that combination which achieves a net minimum steam cost you establish the level of optimum economy. In this case the availability of additional boiler units suggested the alteration of load distribution practice so that the AST characteristic of the more favorable energy value coals could be accommodated. Reduced loads on the boilers might depress efficiencies a little, but the potential savings made this possibility a worthwhile compromise.

After a new load distribution plan was worked out, two new coals representative of the better energy values were brought in for week long trials to compare actual performance with indicated findings. At the conclusion of several weeks' trials the client found that average daily savings would amount to an annual figure

of $23,000, slightly higher than had been anticipated. Actual records kept in the intervening months since our investigations have further demonstrated that the estimated savings will be very close to reality.

Competing Fuels Pose a Problem

Our present-day multi-fuel economy often poses the question of which fuel will affect maximum economy for a given plant. There are pitfalls in this problem which can trap the unwary.

A plant consuming about 45,000 tons of coal per year located within thirty miles of east coast refinery operations was considering conversion of its boiler plant to residual fuel oil. Initial calculations had brought forth an estimate of annual fuel savings amounting to $60,000 if the conversion were made.

The boiler plant consisted of five units, two 100,000 per hr steam generators and three 80,000 lb per hr steam generators, all equipped with eight-retort continuous-ash-discharge stokers. The steam load was characterized by an instantaneous increase of 300,000 lb per hr, from an average load of 140,000 lb per hr to 440,000 lb per hr, that would last for an hour and a half. Sudden load swings of such magnitude are bound to create problems of one kind or another. Totally aside from the economics of the situation, stoker firing offered an advantage over oil because a banked coal fire supplies heat to the setting and water in the boiler, thus keeping things in a condition of readiness for this unusual load whenever it occurs.

After combustion tests and field investigations were completed, the original estimates began to shrink. Average operating efficiencies were low, one boiler actually showing only 60 per cent. Observations disclosed that combustion controls were in need of attention. Examination of coal costs divulged that the client had not been obtaining the best energy values among coals available in the area even though the plant imposed no restrictions on selection.

Research into coal and oil costs during the postwar years at the client's location demonstrated how speculative fuel oil economics could be for this plant. In some localities fuel oil is, and has been for some time, more economical than coal. General proximity to the refineries does not justify any quick assumptions in this respect. Unless a plant is definitely located well within a market area dominated by oil, the assurance of consistently achieving maximum economy can only be had by the dual-fuel plant capable of swinging from one fuel to the other without mechanical alterations or lengthy shutdown.

In the plant under discussion, annual savings relative to existing operation on coal, taking advantage of all possible improvements in operation as well as coal selection, were estimated at $55,000. Thus the conversion to fuel oil was denied the attraction which it had commanded as a result of initial calculations.

Plans were then changed to direct efforts toward better operation on coal. Coal procurement was reviewed continually by our staff and necessary changes were made in the boiler room to raise operating efficiencies to good levels of performance. Subsequent operating experience supported the findings in favor of coal and the plant has remained on this fuel ever since the decision was made.

Researcher seeks quality data from records of over 4000 mines

Production Demands Sometimes Take Precedence

In our expanding economy, the plant often must find ways to obtain greater steam output from existing equipment in order to meet growing steam demands. When production becomes the primary consideration a compromise with economy may be indicated in the form of higher cost coals that will perform satisfactorily under adverse furnace conditions. To hold the increase in steam cost to a minimum and yet avoid operating difficulties, it becomes necessary to determine the values at which various coal characteristics will become critical.

The case of a small machinery manufacturing firm is fairly typical of this type of problem. An average steam demand of 17,500 lb per hr was evenly divided between two single-retort stoker-fired boilers, each equipped with economizer and air heater. Combustion tests revealed operating efficiency close to 77 per cent. The coal in use at the time analyzed as follows:

Moisture	6.0%
Volatile	37.7%
Ash	8.2%
Sulfur	3.8%
Btu	13,050
AST	2160 F

The physical dimensions of the grates yielded a combustion rate with this coal of 27 lbs of coal per sq ft per hr. On an energy basis this coal represented a delivered cost of 27.3 cents per million Btu. The client had negotiated a price competitive with favorable market values for this type of coal.

Dust samples are weighed after filtration and drying

Upon completion of a new building it was anticipated that steam demand would climb to an average 22,500 lb per hr with possible peak demands of 26,000 lb per hr representing 190 per cent of boiler capacity. Allowing for some decrease in efficiency, combustion rates could be expected to reach 48 to 50 lb per sq ft per hr. Such high combustion rates on a single-retort stoker with coal of the above characteristics would lead to serious operating difficulties. This fact would have become disappointingly evident as the new steam load came on the line.

Since the building program would be completed within a month or so, the client had only one choice for the moment if the desired output was to be achieved from the facilities at hand—change to a coal, the characteristics of which would perform satisfactorily at the high combustion rates anticipated. This change, however, meant drawing from coal producing districts with which the client had had no previous experience, and it was deemed advisable to place coal procurement under our supervision.

A purchasing specification was first prepared to meet the client's new requirements. It called for a coal of the following minimum quality:

Moisture	5.0% max
Volatile	35.0% max
Ash	8.0% max
Sulfur	1.0% max
Btu	13,000 min
AST	2700 F min

The client was advised of several sources from which to request bids on coal of this type. Each bid was carefully scrutinized and compared with available quality records to be sure that it would consistently meet the minimum specification and that the price truly reflected quality. The final selection on an energy basis represented a delivered cost of 30 cents per million Btu. This was equivalent to a compromise of 75 cents per ton above the previous coal.

It was discovered during the investigation that greater advantage could be made of the available furnace space. Furnace dimensions would allow for an active grate area of 56 sq ft. The installed combustion equipment had an active grate area of only 33 sq ft. Expansion of the grate area could decrease the combustion rate of the anticipated loads to around 25 lb per sq ft per hr and allow a return to the more economical coal.

Since this plant was a 5000-ton-a-year consumer the 75 cents per ton increase in fuel cost would represent $3500 to $4000 per year. This sum would represent such a long payout on the investment needed to install larger stokers that it was judged prudent in this case to accept the compromise of higher cost coal instead. Incidentally this plant had become inured to chronic maintenance problems which ran their maintenance expenses up close to $5000 per year. The client reported later that adoption of the more expensive coal had so reduced their maintenance costs that it completely offset the increased fuel bill.

A Chance to Plan for Maximum Economy

Sometimes the need for replacement and the need for expansion of the boiler plant coincide. When this occurs a genuine opportunity exists to plan new facilities around sound engineering and economic principles unfettered by requirements of compatability, space limitations, or other compromises. This opportunity places a clear and definite responsibility upon management to seek facilities which offer the best promise of generating steam throughout their useful life at most favorable cost.

A progressive New York state company successfully met this challenge by taking specific action as they saw the day approaching when additional facilities would be needed. Their boiler plant consisted of three 225-hp Heine boilers installed in 1925. Steam demands had grown from an average 209,000 lbs per day representing 60 per cent of boiler rating with two boilers on the line to 650,000 lbs per day equalling nearly 120 per cent of rating with three boilers on the line. It was necessary to operate three boilers continuously, and any down time meant a loss in production. Completely new facilities were indicated considering the age, general condition, operating costs, and adaptability to modernization of these old boilers.

Since fuel is the largest single operating expense incurred in the generation of steam, it contributes the largest element to the cost of steam. At the client's location it was judged that coal offered the best promise for representing the lowest cost source of energy over the long pull. Detailed coal studies were then started with a comprehensive investigation into sources of supply covering the producing districts which the client could tap. Freight rates, prices, reserves, and trends in productivity per man and total production were ascertained. Typical coal characteristics from each area were determined, and minimum qualities noted. From this work evolved the limits in coal characteristics which the future plant should be able to accommodate in order to continuously take full advantage of competitive features of the coal market.

While this work was in progress, steam flow meters were installed in strategic lines to develop information on process steam requirements. In the past a favorable heat balance had made the generation of process steam and electric power an advantageous mode of operation, and a study of electric power needs was also undertaken.

From these data and the client's predicted production demands, future steam loads were synthesized, and the steam generating capacity of the plant began to take shape. Three 25,000 lb per hr units were indicated. Once the unit size of the boilers was settled, the necessary information was at hand to choose combustion equipment compatible with these boilers and the coal characteristic requirements developed earlier. Spreader stokers satisfied these requirements with the added advantage that they represented comparatively low first cost.

The careful planning stages which preceded the design and construction of this plant enabled the client to keep capital expenditures to a minimum with the assurance that no essential to efficient economical operation had been sacrificed. Several years subsequent operation have shown the wisdom of the decisions made.

Concern for the Public Interest Is a Management Challenge

Particulate matter which momentarily is transported in the atmosphere under the action of wind, but which due to its size and density, manages to come under the influence of gravity and become deposited has been termed "dust fall." Although the permissible contribution to dust fall from the chimneys of industrial boiler plants and processes has escaped definition, public sensitivity in regard to this matter has become a force to be reckoned with. More and more, legislation is placing the burden to have regard for the public interest upon those whose operations discharge dusts into the atmosphere. To help management cope with the practical problems which this situation creates, the author's company has been developing, over the past twenty years, techniques that have proved reliable and useful for measurement and identification of stack emission as deposited in a given area.

A chemical plant in a mid-south city became concerned about what their contribution to dust fall might be after a number of complaints had been received. This city, because it had little heavy industry, and used natural gas as the major fuel both for homes and industry, had an unusually high standard for air purity, a fact that was brought out in the subsequent study that was undertaken. The economics of the process carried on at this particular plant dictated the use of waste products as boiler fuel. Although the plant had originally been outside the city limits, the city had now grown around it.

A new boiler unit, also to use the waste fuel, was in the planning stage and would probably be completed in two years. The general manager of the plant was interested in a survey of the situation to determine how his stack discharge compared with others in an industrial area; what percentage of the material complained of originated from his plant; and what atmospheric conditions contributed to the complaints.

A plan of procedure utilizing wet traps was established after an investigation of local topography and peculiarities of the stack effluent had been determined. Each trap presented a wet surface to falling particles at all times. An inhibitor was added to control bacterial and fungus growths. A fixed trap exposure interval of two weeks duration was adopted. The quantities of waste fuel burned during each trap exposure interval were listed and weather data recorded. Six sites were chosen for the traps, the nearest of which was 2400 ft from the stack and the farthest 6720 ft.

At the end of each trap exposure interval the contents of each trap were filtered through an alundum cone, and after drying, the weight of insoluble matter was determined. The filtrate, meantime, was evaporated to dryness to determine the character and amount of the soluble material.

Periodic reports were prepared which summarized weather data, wind direction, and breakdown of trap contents. The rate of dust fall was expressed as grains per sq yd per week (GSW)—numerically practically identical with tons per sq mile per month.

Early findings were quite reassuring to the client. The solid matter deposited in the traps was recognized as being predominantly a miscellaneous conglomeration of natural dusts consisting of sand, fibers, and vegetable matter. To a lesser extent trap contents consisted of material the characteristics of which were similar to emission from the client's stack.

Our knowledge and experience with dust fall has led to the acceptance of a more or less arbitrary zone classification according to the range of dust fall experienced. These zone classifications, according to the dust fall in GSW, are as follows:

Zone	GSW Range
Residential	0–50
Commercial	50–120
Industrial	Over 120

Average total dust fall during the two years preceding operation of the new boiler unit was 34 GSW. There was a slight tendency toward a seasonal variation with higher dust fall rates occurring in January and February. However, this low dust fall rate definitely established the client's stiuation far below industrial areas in other cities. The client gained the greatest measure of reassurance from the fact that during this period his average contribution to total dust fall was only 5 GSW or less than 15 per cent. His maximum never exceeded 10 GSW.

Results obtained after the new boiler came on the line and assumed the load brought the survey to its conclusion. Continuing for six months after the new unit was lighted off, it revealed an average total dust fall of 36 GSW while the client's contribution dropped to trace amounts.

Conclusion

Returning to the title of this article, it does take more than fire and water to make steam. Economic and social factors, which challenge man's very ingenuity and charge him with new responsibilities, are continually demanding attention at every turn. But sight should not be lost of the fact that they can be the source of economic potential equivalent to as much as 15 per cent of the annual fuel bill and also better neighborhood relations around your plant site.

Corrosion and Deposit Control in Cooling Water Systems

This article attempts to explain the origin of the problems dealing with corrosion and deposition encountered in cooling water systems and to describe some of the more common types of treatment.

By CRAMER H. COOK

Cyrus Wm. Rice & Company

THE electrolytic theory of iron corrosion describes corrosion as the process of metal entering into solution forming positively charged ions. This constitutes the first half of the reaction, with the other half being the plating out of hydrogen ions from the water, forming a molecular hydrogen film at the interface. The half reactions are anodic and cathodic, respectively. The theory further indicates that the corrosion process would stop at this point if the protective hydrogen film were maintained. However, a number of items such as velocity, difference in concentration and temperature between the interface and the main body of water, and the natural movement of ions in solution tend to remove the protective hydrogen film and the corrosion continues at a rate equal to the rate that the hydrogen film is removed.

The types of corrosion generally encountered in circulating cooling water can best be described as to the appearance of the attack as observed from inspection of the unit. Pitting or localized attack can generally be attributed to the presence of dissolved oxygen. Tubercules are heavy buildups of corrosion product over a pitted area and form in places of low flow or where extremely rapid corrosion is occurring. The tubercules in these cases form excellent environment for further corrosion of microbiological origin as in the case of sulfate reducing bacteria. The tubercule encrustation in this case provides somewhat of a barrier against algaecidal or germicidal agents such as chlorine. The sulfate reducing bacteria secrete an acid which promotes metal attack. It is also possible to have a generalized attack which would normally be encountered with a corrosive type of water having characteristics of low pH, or a water having a pH considerably lower than the theoretical pH at which the water would be saturated with calcium carbonate, which will be discussed more fully under deposition. Corrosion by internal or external electrolysis may be due to the immersion of two commonly connected dissimilar metals in water solution. The external electrolysis may be due to external voltages from a piece of electrical equipment within or near the plant.

The deposition which causes fouling and scaling in cooling water systems and reduces heat transfer and increases pumping heads is another serious problem. It is related to corrosion in that the fouling or reduction of heat transfer may be due to the deposition of the corrosion products. Usually, in this case, the deposition is composed of iron oxide. The most common scale encountered in cooling waters is calcium carbonate, although calcium sulfate and possibly magnesium silicate may be found. To more fully understand the formation of these deposits, it is desirable to examine the solubilities of the more common scale producing items in water, Table I.

TABLE I—SOLUBILITIES, Terms ppm $CaCO_3$

	32° F	212° F
$Ca(HCO_3)_2$	1,620	80% decomposed to $CaCO_3$
$CaCO_3$	15	15
$CaSO_4$	1,290	1,250
$Mg(HCO_3)_2$	37,000	80% decomposed to $MgCO_3$
$MgCO_3$	101	75

As you will note, the chemical compound of least solubility is calcium carbonate which is present in the makeup water directly and is formed by heating the bicarbonate in the water.

The original carbonate concentration, plus the amount of carbonate formed from the breakdown of the bicarbonate, is concentrated in the recirculated water due to evaporation losses of the system.

The Langelier Index of a water is the log of its degree of calcium carbonate saturation. The pH_s as computed by the Langelier Index is the pH at which the calcium carbonate present in a given water would be saturated. If the actual pH is higher than the pH_s, the water is said to have scale forming tendencies. If the pH of the water is lower than the calculated pH_s, the water has corrosive tendencies. The pH_s depends upon such factors as temperature, total dissolved solids, calcium hardness, and total alkalinity. In each instance, with the exception of an increase in the total dissolved solids an increase in any of the variables results in a decrease in the pH_s value, or in other words the water scale-forming tendency is increased. A slight decrease in the scale-forming tendencies of a water is theoretically effected by an increase in the total dissolved solids value; but actually an increase in dissolved solids in a tower is usually accompanied by an increase of calcium hardness and alkalinity, which by far outweighs the increase in solubility gain by the increased dissolved solids concentration, and the net result is an increase in scale-forming tendency.

The foregoing suggests the treatment for the deposition of water deposits: that of maintaining the various constituents in the water soluble at the temperature involved. Since in cooling water treatment there is little possibility of altering materially the temperature of the water involved, the scale-forming tendencies of a water must be controlled by maintaining the calcium

hardness, total dissolved solids, and total alkalinity at desirable concentrations.

Another type of deposition or fouling which is encountered in cooling waters is caused by algae growth. This bacterial growth is visible in the form of slime and sometimes the same possesses a cellulose membrane like higher plant life. This membrane forms a gelatinous film on surface of heat exchangers and collects sand and other debris, reducing heat transfer and retarding water circulation.

Treatment of Cooling Water

In order to intelligently consider the proper treatment for cooling water, it is necessary to know (1) the circulating rate of the tower, (2) estimated windage loss, (3) temperature drop across the tower, (4) maximum temperature encountered, and (5) analysis of the makeup water to the tower.

For obvious reasons, it is desirable to select the best and most economical water supply as makeup for cooling water purposes. In some cases the makeup water quality is such that pre-treatment of the water is required. This pre-treatment may be softening by zeolite or ion exchange, partial softening and/or reduction of alkalinity by treatment of lime and/or soda ash, coagulation in the case of surface and river waters, degasification, and in some cases dealkalizing by anion exchangers. These apply generally to a poor quality of makeup water; are usually individual problem cases and will not be taken up in detail in this paper.

Calcium Carbonate Controlled Film (Langelier Index Control)

As was indicated previously, the calcium carbonate saturation pH is a method of treatment control for the prevention of both deposition and corrosion. The Index is used as a tool or guide to deposit a thin protective $CaCO_3$ film on the metal surface, yet not permit too great an amount of deposition to take place. In this case, the pH of the water is usually maintained in the range of plus or minus 0.5 pH units of the calculated pH_s value and is accomplished by the addition of acid or caustic. The pH adjustment therefore, provides a measure of control of the final pH of the water and the alkalinity concentration. It is usually also necessary to control the total dissolved solids concentration and maintain the same at the desired concentration level, or range of concentration, by blowdown. This type of treatment can be applied successfully provided the testing and treatment control is carefully and precisely executed. The success of this type of treatment requires that the temperature variance over the tower be not too great. With a temperature variance of a hundred degrees Fahrenheit, which is not uncommon, it is possible to have a pH_s variance of about 1 pH unit which is sufficient to cause severe corrosion. This factor, together with the variance in actual pH, total dissolved solids, and calcium hardness impose continual difficulties with the successful application of this type of treatment. It is, however, the treatment method that can be applied most economically and successfully for towers requiring large amounts of makeup water or for once-through cooling systems. It is of further advantage to utilize corrosion resistant materials in cooling systems at points of most severe corrosion attack. Materials which have been used with success in areas of high sensitivity for corrosion include lead and 18-8 stainless steel (1)[1]. Bitumastic paint, if properly applied, has been found to be effective in reducing corrosion on floating heads.

Algae and Slime Control

Chlorination is the most commonly used agent for the control of organic slimes and algae growth. The chlorination may be either continuous or consist of intermittent slugs. The general practice is to maintain the chlorine residual at 0.2 to 0.5 ppm by continuous feeding, or feed chlorine at higher residuals nearer 1.0 ppm or greater during the intermittent slug feeding. Other agents that are used with very good success and apply particularly to the smaller towers are sodium hypochlorite, quaternary ammonium salts, sodium pentachlorphenate, phenolic compounds, and potassium permanganate. Copper sulfate has also been used but should be applied with care due to its toxicity, and the fact that copper sulfate can cause corrosion if the copper becomes plated out on iron surfaces. In this case a galvanic cell is set up with iron as the sacrificial metal. With continual feeding of an algaecide, the microorganism often builds up an immunity to the specific algaecide. It, therefore, becomes necessary in some cases to increase the feed rate of the algaecidal treatment at intervals or to utilize a different algaecide for a period of time. This problem seems to be more acute in regions of year-round warm weather. In regions of periodic cold weather, the algae is killed off during the winter, and it would appear that the strain does not have sufficient time to build up the immunity during its seasonal life span. In most cases, algae control in a tower is a must unless the specific inhibitor employed for corrosion protection also possesses a high toxicity to the bacteria or algae normally encountered.

Inhibitors Commonly Used for Corrosion Prevention

Hackerman and Makrides (2) explain inhibition as a result of both increased resistance to current flow caused by electrostatic adsorption at cathodic areas and from anodic polarization caused by chemisorption. The relative contribution of the two depends on the inhibitor. Three classes of inhibitors may thus be distinguished. Anodic inhibitors function by polarizing anodic dissolution. An example is the sulfide series. A second class consists of mixed inhibitors. Examples are amines and thiols. Finally, there are cases where cathodic polarization is the most important effect. Quaternary amine salts belong to this class. Here, although physical adsorption probably occurs over the entire surface, chemisorption does not take place since there is no possibility of electron transfer.

Most inhibitors are efficient in a limited pH range. In general, it is usually found that organic type inhibitors exhibit better corrosion protection in the acid range below pH 6.0, while inorganic inhibitors appear to work best in the high pH range, above pH 7.0. Therefore, the inhibitor selected for use should be utilized in its range of effectiveness, and the effective pH range must satisfy a slightly negative calcium carbonate pH of saturation for the particular water if deposition is to be elim-

[1] Numbers in parentheses refer to Bibliography at the end of the article.

inated unless the inhibitor has further action such as suppressing the saturation index of calcium carbonate by sequestration or dispersion of one of the significant Langelier Index variables.

Chromates

It is the generally concluded theory that iron passivity is achieved through the use of chromate by formation of a dense adherent deposit of mixed ferric and chromic oxide on the anodes. This would account for the fact that chromate consumption occurs upon initial treatment of a cooling water system. It is the writer's belief that inhibition is achieved by the formation of trivalent chrome at the interface; that the metal initially corrodes forming magnetic iron oxide (Fe_3O_4) which reacts with the chromate at the interface, and the chromate is reduced to the trivalent form and anodic chemisorption takes place. This theory is further substantiated by the fact that when systems are treated where corrosion has been intense and there is excessive corrosion product (Fe_3O_4) in evidence, the chromate is excessively consumed and chromic salts may deposit out in the heat exchanger system and inhibition is not readily achieved. The chromate in this instance is not available at the interface since it only came in contact with the corrosion product where it was reduced or in effect consumed and could not achieve inhibition. Acid cleanings of systems of this nature followed by chromate treatment have been found to be the successful remedy of this problem.

Chromate treatment is generally applied and maintained in the range of 300–500 ppm with the pH of the water controlled in the range of 7.5–8.5. The treatment has been very satisfactory in many instances. Treatment costs can, however, be exorbitant for large towers requiring high makeup. In addition, there are plants where process leakage can be an important factor in the successful use of chromate treatment. If the process leakage consists of reducing agents such as hydrogen sulfide gas or mercaptans, the chromate will be reduced to the trivalent form, this time in solution, and the chromic salts will deposit out in the heat exchangers. As a result inhibition on the metal surfaces may not be complete due to lack of sufficient chromate concentration at the interface as indicated in the preceding paragraph. In fact, exceedingly low chromate concentrations have been found to actually accelerate corrosion rates. Also, the nuisance value of chromate is high particularly in congested areas where the water spray may be carried by the wind and cause damaging effects to clothing, and other materials due to yellow discoloration.

Polyphosphates

As inhibitors, polyphosphates passivate by adsorption. They act as cathodic inhibitors. They will, also, by the threshold or sequestration effect retard scale formation by increasing the calcium carbonate saturation index. They have been used successfully in concentration ranges of 10–15 ppm and as high as 50 ppm in pH ranges of 7.0 to 8.0. The polyphosphates' disadvantage is in their property to revert from the polyphosphate to the orthophosphate form, in the presence of water, the reversion process being controlled by time and temperature. In the orthophosphate form, they will precipitate out with the calcium hardness in the water as calcium phosphate if the solubility of calcium phosphate is exceeded. Thus, the treatment must be controlled such that the solubilities of both calcium carbonate and calcium phosphate are not exceeded in the system at the temperatures involved. The polyphosphates are, therefore, best adaptable to systems of low hardness and where not too great a temperature difference over the tower is encountered.

Chromate-Polyphosphates

The combined chromate phosphate treatment has been used in a number of instances. In some cases where deposition was encountered in the high chromate treatment of 300–500 ppm, polyphosphate in concentrations of 5–15 ppm was added to prevent deposition of calcium carbonate by increasing the Langelier Index pH_s value. Also, a low phosphate chromate treatment has been used of approximately 20–30 ppm chromate and 30–50 ppm polyphosphate in the pH range of 6.0, or in the pH range required to prevent the deposition of calcium carbonate and calcium phosphate. The polyphosphate in this case serves a dual action in the way of increasing the solubility and also as a dispersant to aid the chromate in its effect as an inhibitor at the interface. The low inhibitor concentration effect which may actually accelerate corrosion and the possibility of depositing calcium phosphate are the disadvantages of this type of treatment. The cost of this treatment, however, is sufficiently below that of the high chromate treatment to make it worthy of consideration and use in many installations, and it has been shown to be successful in corrosion inhibition providing the treatment control is adequately maintained.

Silicates

Silicates have been used for corrosion control and their protection is thought to be afforded by a gelatinous film of mixed ferrous oxide and colloidal silica. The literature would indicate that the exact form of silica that affords the protection is not known. The silicate is generally fed in the concentration of 25–50 ppm. The treatment necessitates maintaining a slightly negative calcium carbonate saturation pH to prevent the deposition of calcium carbonate. It would appear that the silicates, or a form of silica is a good corrosion inhibitor; but difficulty is often encountered with very hard deposition which forces early outages of equipment which offsets the effectiveness against corrosion. The deposits, if encountered, which are formed in the high temperature zones, are extremely hard and difficult to remove. Unless more knowledge can be gained in the control and treatment with silicate, the method will continue to be one of trial and error (3, 4).

Silicates-Polyphosphates

This combination of chemicals has been used in the pH range of 6.5–8.0 depending upon the water. The silicate again, or a form of it, is attributed for the corrosion protection by film formation and the phosphate is primarily beneficial in controlling deposits.

Polyphosphate-Cyanide

Combinations of sodium cyanide and polyphosphate have been used for corrosion protection. The cyanide

concentration used is of the order of magnitude of 5–15 ppm and polyphosphate in the range of 20–50 ppm. The most effective pH range is generally between 5.0 and 6.5. The treatment imparts a bluish color to the metal surface. The treatment has been found to be satisfactory, but imparts a waste disposal problem.

Chromate-Phosphate-Zinc

Zinc concentrations in the range of 0.8–10.0 ppm have been used in combination with chromate and phosphate for corrosion inhibition. Zinc is used in the soluble and coating ranges. The material forms a very dense coating on equipment and heat exchange surfaces. The success or failure of the method would apparently lie in controlling the dense heavy film which is laid down during treatment. The treatment control, therefore, must be exceedingly precise and not too great temperature changes can be tolerated without difficulties.

Other

A number of organic inhibitors have been used in cooling water treatment. Among them are the glucosates and their salts, quaternary ammonium salts, rosin amine D acetate, and many others. As was indicated previously, the organic inhibitors generally show better corrosion protection in the lower pH band. This greatly increases the required treatment to most systems in requiring additions of acid for lowering the pH. Also the organic inhibitors generally are quite expensive.

Treatment Calculations

In order to estimate the required treatment of a cooling tower, it is necessary to know the makeup. The makeup of a tower is the sum of the water lost from the tower by evaporation, windage, and blowdown. The evaporation losses of a tower can be estimated by assuming that for each 10°F. difference in the water passing through the tower, the makeup is approximately 1 per cent of the water circulated. Typical windage losses for a mechanical draft tower is approximately 0.2 per cent, for atmospheric towers $^1/_2$ to 1 per cent, and for spray ponds 2–5 per cent on the basis of the circulating rate.

For equilibrium conditions, the solids entering the cooling water system must equal the solids leaving. The following formula is useful in calculating the number of concentrations taking place in a cooling water:

let E = evaporation

W = windage, B = blowdown } Sum of which = Makeup

S_m = solids in makeup

S_r = solids in recirculating stream

C = number of concentrations

Then: Since "solids in" must equal "solids out".

$$(E + W\,B)\,S_m = (W + B)\,S_r$$

Also, number of concentrations

$$C = \frac{S_r}{S_m}$$

Therefore,

$$C = \frac{E + W + B}{W + B}$$

The maximum concentration obtainable would, of course, be with zero blowdown, in which case

$$C\ \text{max.} = \frac{E + W}{W}$$

From the makeup water, it is necessary to determine the maximum allowable number of concentrations which can be permitted to take place in a tower. The number of allowable concentrations can then be substituted in the formula below to determine the required blow down of the tower.

$$B = \frac{E + W\,(1 - C)}{C - 1}$$

In initially treating a tower, the volume of water in the tower can be estimated as that equal to 40 times the total possible circulating rate of the water

BIBLIOGRAPHY

1. L. N. Scharnberg and E. F. Lynch, "Experiences with Corrosion and Deposition Control for Cooling Tower Systems in an Oil Refinery" (article presented at the 14th Annual Water Conference, October, 1953).
2. Norman Hackerman and A. C. Makrides, Technical Report to the Office of Naval Research, "The Action of Polar Organic Inhibitors in the Acid Dissolution of Metals," October, 1953 (copy obtainable through U.S. Department of Commerce, Office of Technical Services, price 50¢).
3. J. K. Rice, "Treatment of Recirculated Cooling Water," Presented at the 1952 NACE Conference.
4. R. C. Ulmer and J. W. Wood, "Prevention of Corrosion in Cooling Waters," *Corrosion*, 8 No. 12, 402 (December, 1952).

It's going on all the time!

Foreign solids accumulate in boilers continuously. If you would hold the concentration within suitable limits it follows that removal must also be continuous. You cannot expect to maintain efficient trouble-free steaming by blowing now and then; but too often you can expect to upset the load balance and waste a lot of heat units as well as money down the drain. Why not learn about the modern way to blow boilers, save trouble, save money and avoid stress upon equipment; write for catalog on "Correct Blow-Off" to *The Madden Corp., 1543 W. Morse Ave., Chicago 26, Illinois.*

The Importance of Fuel Research*

By EUGENE AYRES, Consultant

Gulf Research & Development Co.

A complete break with conventional fuel technology that will spark a capital invention in energy release and conversion is held by the author to be vital to our development.

NOT so many years ago I asked a brilliant engineer how he would define *research*. He said: "Any technical investigation that never pays out." This man was responsible for many new things that paid out handsomely, but he refused to designate his own work as research.

This was in the 1920's. As the years have passed, the definition of research has undergone a radical change. Today the general attitude toward the word is almost one of veneration. Research has become synonymous with progress, and progress with profit. No one any longer questions the importance of research—so you may well ask: "Why talk about it?"

But we are concerned here not with the impressions of those who benefit by progress, but rather with the specific viewpoints of those responsible for progress. For research means many different things to many different technologists. There are so-called pure scientists who explore exotic scientific ideas that may eventually lay secure foundations for future inventions. There are so-called practical engineers who apply experience and ingenuity to development. Both are important. Some research projects are not consciously related to profit, some are highly speculative, while others have a conservative investment flavor. The attempt to discover something new and useful may or may not be successful, but the improvement or "perfection" of something already conceived can be depended upon to yield rich returns. This is, of course, why modern organized research lays particular stress on development, but a good program portfolio is always leavened with some promising speculative projects. The ratio of investment to speculative research usually runs about four to one in modern well-managed departments.

These different conceptions of research, with those of intermediate character, all have their own obvious importance to our economy, but what I plan to talk about is another kind of research—one that is being largely neglected today. This subdivision may be classified as fundamental but is not academic. It is not being pursued consciously by universities, by government, or by our great industrial research laboratories. It is not stimulated by technical learning, by specialization, by competent management, or by effective organization. Furthermore, it does not appear to be a particularly characteristic part of American tradition.

So much for what it is not. Sometimes the outcome of this sort of research is evolution of some important new idea. Sometimes it is development of an idea. But it is always characterized by its profound effect on our economy. It may, therefore, be conveniently defined as *capital invention*, as distinguished from supplemental invention, or minor basic improvement in an art. Capital inventions come along infrequently, partly because we technologists find it difficult to get out of the grooves of our own making, and partly because capital inventions have seldom been financially rewarding to the inventor. (Perhaps the motor car development of Britain's Harry Ferguson at seventy-two is the exception that proves the rule.) Capital inventions are often made by the poorly educated, by the technical nonconformist, or by the socially maladjusted individual. But they have been the cornerstones of material progress.

The development of the art of converting heat to power began about two and a half centuries ago. Most of you are familiar with charts showing improved efficiency of conversion in terms, for example, of pounds of coal required per unit of power (expressed in terms of kwh)—how the Newcomen engine was gradually improved during the 18th century, how the Watt engine brought about a sharp improvement toward the end of the century, how efficiency remained almost stationary for more than a century—until Parson's steam turbine brought about another sharp jump—and how the efficiency of the turbine has been gradually improved during the 20th century. During two hundred and fifty years only three really capital inventions have been made in this art (excluding the capital inventions in the electrical art). Each engine in turn has been gradually improved almost to a practical limit, but substantial changes have come only when these limits have been pushed back by new physical concepts. Today we have almost reached the practical limit of turbine efficiency (not far from the theoretical limit). The time is at hand for some young imaginative inventor to conceive of a way to get in the form of electric power much more than a third of the energy represented by heat of combustion fuel or of nuclear reactions. (In Latin America the proportion is less than one-sixth.) In the light of technological history it is inconceivable that this will not happen. There is no theoretical compulsion in the idea that bulk power can be produced only from heat. (Even hydropower has its origin in the heat of the sun.)

Most major and minor power and heat developments have been concerned with machines rather than with ways to obtain maximum heat from combustion, but it is idle to attempt to distinguish between the two kinds of research. Fuels are useful as fuels only when they can be adapted to equipment for generation of heat or power, just as food must always be associated with an appropriate consuming organism. When equipment is modified, fuels must often be modified also to secure optimum results. The converse is equally true. The fuel and the equipment in which it is used must be considered together.

---

* Presented before The General Meeting, American Institute of Electrical Engineers, Jan. 30–Feb. 3, 1956, Statler Hotel, New York, N. Y.

A press account of the discovery of the antiproton ended with a reference to the evidence that the collision of an antiproton with a proton would lead to conversion of the two particles to "pure electric power." This was, of course, the poetic license of a journalist. Electric power, as we know it today, involves narrowly specialized arrangements of electron flow. Any device for random production of radiation from nuclear reactions or from chemical reactions of combustible fuels must be followed either by invention of equipment for inducing such specialized arrangements of flow or by discovery of another form of transmissible power. The only reason that we are limited today to wave lengths of around 10^{16} angstroms is that the electrical art has grown up with this wave length. In the meantime we must be content with the same primitive conceptions of power generation that evolved in the latter half of the 19th century—and this applies, of course, both to combustible and to fissionable fuels.

Perhaps electric power will not come fully into its own as the world's predominant form of useful energy until new capital inventions are made, until we are not limited by the efficiency of the steam cycle, until bulk storage of power is economically feasible, and until transmission at long distances is possible without inordinate loss. Some such capital inventions may have already been made. The importance of a new discovery is not often apparent until development is well under way. The direct electronic conversion of solar radiation to electric power may be a landmark in energy technology. Only time will enable us to be sure.

The use of electric power in the United States appears to be growing at the rate of around 8 per cent per annum. This can hardly be considered a reason for surprise or special gratification. Annual increments of even 10 per cent are not uncommon in our energy economy. Continued annual increments of 10 per cent would mount up to a one-hundred-fold increase in fifty years (which would seem formidable enough to public utilities), but during the past fifty years the total capacity of the world's equipment for production of all kinds of power from heat increased about one-hundred-fold. This includes, of course, the internal combustion engine. The consumption of petroleum in the world outside the United States increased during the past ten years at an average rate of 10 per cent per annum. During the past seven years industrial production in the United States increased only 33 per cent while in the rest of the world the increase was 74 per cent. Accordingly, in this country the rate of increase in petroleum consumption appears to be declining a little—is now consistently under 10 per cent per annum. This is a natural consequence of gradual approach to saturation of our economy with motor vehicles. The average rate of increase in petroleum consumption over the next two decades is expected to be about a third of that of electric power. But the average rate of increase in consumption of motor fuel has been above 10 per cent per annum in the United States. In general, the rate of increase for motor fuel outside the United States has been higher than that for electric power. For example, in Latin America the rates of growth have been about 5 per cent for electric power and 6 per cent for motor fuel.

Consumption of fuel for generation of electric power is about a fifth of the total consumption of fuel for power purposes in the United States, and for several decades this proportion has shown no marked tendency to rise. In spite of its relatively low cost and its generally attractive features, electric power is still far from predominant even in the power category. Successful development of economical nuclear power is not the answer if fissionable material is to be used merely to generate a part of the heat that would otherwise be generated by the combustion of only about 12 per cent of our total annual fuel supply.

If revolutionary forms of electric power should actually be conceived and developed, present-day generators, motors, and appliances might become obsolete, but the eventual effect on our economy should be favorable by extending the scope of electric power applications. I believe that most of us have an intuitive faith that electric power is at an early point in its growth curve, and that in the world of tomorrow we shall utilize electric power for almost all of our energy needs, including space heating. The market for space heating is now almost three times the total electric load in the United States.

An example of a power type that is generally believed to be well advanced in its growth curve is motor fuel. A reason for this in the United States is the gradual approach to saturation of our economy with motor cars, to which I referred a moment ago. But a fundamental reason for the world as a whole, which is very far from saturation with motor vehicles, is that the production of petroleum is approaching a peak. The most authentic computations indicate that the peak of domestic production in the United States may come around 1965. The peak for the rest of the world may be around 1980. Motor fuel will still be available for a long time after these dates, perhaps even in abundance, but costs will reflect the pressure of demand to be satisfied in part by the greater difficulty in discovery and production of petroleum, and in part, by relatively expensive conversion of oil-shale and coal to liquid fuels. The pinch will come, of course, before the peaks of production. If demand trends of the past decade should continue, it looks as though world shortage of natural petroleum may start four or five years from now.

What part can be played by research in this dilemma? The problem is serious for the United States and for other highly industrialized nations but it is far more serious for underdeveloped countries. We have had our amazing industrial expansion at a unique period in world history—a period characterized by a happy confluence between a certain state of technology and availability of cheap oil. Capital invention in Europe toward the end of the 19th century gave the world an internal combustion engine that was suitable for development to the present state of superlative functioning with petroleum distillate. In development it has been unnecessary to think much about efficiency. With motor fuel as cheap as bottled water we have preferred performance to economy. Development could achieve performance but only capital invention could achieve economy.

Technologically, electric power is much more advanced than motor vehicle transportation. Electric power generation shook off the reciprocating engine half a century ago. The automotive turbine (except in airplanes) is still in the future. Electric power generation is approaching the theoretical efficiency of the steam

cycle, while the motor car has about the same efficiency as the now obsolete coal-fired locomotive. The reason for capital invention in electric power generation is to make it possible for electric power to fulfill its apparent destiny. The reason for capital invention in automotive transportation is to perpetuate its existence. We take it for granted that we shall always have automotive transportation. We may, therefore, take it for granted that capital inventions will be made in this field. These could lead to obsolescence of vast amounts of technology and equipment, but the ultimate effects on our economy should be favorable. Widespread automotive transportation will not be permanently denied to the majority of the world's population merely because they have not consummated their development in the first half of the 20th century, but have delayed until inadequate supplies of petroleum must be limited to the highest bidders. Underdeveloped countries, even those with great petroleum reserves, have already missed the boat—the petroleum boat—but research is bound to bring other boats over the horizon.

The answer to the automotive problem is in the deep shadow of the future. Speculation is tempting but dangerous. Will nuclear fusion be developed for such applications? Will someone devise an electric storage battery of phenomenal capacity? In "The Forseeable Future," physicist Sir George Thomson, refers to the internal combustion engine as an "anachronism" that will be wholly obsolete as soon as a satisfactory "electrical accumulator" has been devised.

While we wait for such radically new and desirable outpourings of technical genius, we must do all we can to prolong the life of present automotive technology by improving methods of finding and producing oil reserves and by finding ways to manufacture cheap liquid fuels from solids. The pressing need for better ways to find and produce oil is highlighted by the expressed opinion of distinguished geologists that the last two-thirds of the world's ultimate reserve of petroleum will not be *found* for some decades after peaks of production have passed, and that only a minor proportion of offshore reserves can be produced with presently known methods.

In spite of our recognition of the eventual importance of supplemental liquid fuels, so far we have spent most of our research effort on development of the ancient Scottish process for retorting of oil-shale and on development of German processes for conversion of coal. Conventional retorting of oil-shale, when combined with improved mining technology, may prove to be good enough, but perhaps liquefaction of oil-shale *in situ* without mining may be achieved by nuclear fission if some way can be found to avoid rapid poisoning of nuclear fuels with by-products of fission. This may be an example of the many ways in which nearly all of the heat of fission might be utilized instead of only a third as in the generation of electric power.

The German processes for coal-conversion suffer from a fundamental defect. Too high a proportion (nearly half) of the Btu value of the coal is lost in conversion. Aside from violence to principles of conservation, this would make costs inordinately high when the price of the coal raw material rises to reflect high demand. This rise seems to be in the offing. We have been accustomed to thinking of coal as an abundant resource, and demand has been relatively minor. The former is incorrect and the latter is certainly temporary.

The latest statistics of the U. S. Geological Survey can be interpreted to indicate that bituminous coal, mineable at anything like present costs, can be produced for little more than a decade at a rate sufficient to take care of such conventional demands as generation of electric power. If none of this "cheap" coal is diverted to liquefaction, the peak of production will come around 1970. Unless nuclear power can take a goodly part of the load, the pinch will come well before 1970. If nuclear power can be developed to fulfill its promise, it will not be competing with this "cheap" coal but with more expensive coal of good quality and with coal of inferior grade such as subbituminous and lignite. By the same token, the raw material for liquefaction will be either more expensive or poorer in quality. Some really new ideas for conversion of coal are imperative.

An old idea that might merit more corporate and technological development is to combine generation of electric power with manufacture of liquid fuel. This would involve carbonization of suitable coal of inferior grade under circumstances favorable to production of maximum tar, and combustion of residual char to raise steam. The creation of such an "energy industry" seems to be a logical way of applying the technology we already know, because Btu loss and overall costs would be minimum. But logical development of old ideas is beyond the scope of this discussion.

In the United States we consume about four times as much fuel for transportation as we use to generate electric power. Motor fuel is much more expensive than coal or residual oil. So excluding taxes we pay out about forty times as many dollars for automotive fuel as for stationary power-plant fuel. The fuel research most important to our energy economy is concerned, therefore, with transportation of people and materials, but such research has scarcely begun.

If we gage the importance of capital invention by the degree of impact on our energy economy we must look for discontinuities in the curves of progress. By this gage we must conclude that no important capital inventions have been made in the field of automotive transportation during the 20th century. No one has shown a way to multiply the 5 per cent efficiency of the motor car by five or even by two. Brilliant developments in mechanical engineering design of automotive power plants, in hydrocarbon chemistry, and in chemical engineering design of processing equipment have accomplished the maintenance of a low cost for motor fuel and the ever increasing power and flexibility of the motor car, but the net result is not encouraging. Consumption of gasoline per motor vehicle is more than twice as high today as it was in 1920, and the comparisons per passenger-mile and per ton-mile of freight are even less favorable. The reasons for retrogression are largely sociological—more traffic congestion, higher use-factor, higher speeds, excessive potential power, larger cars, and more devices for comfort. But even without our insatiable appetite for luxury, automotive efficiencies have shown only the gradual improvement that characterizes the course of development during relatively stagnant periods between capital inventions.

The dieselization of railway locomotives was a step in the right direction but, like many other good things,

it came almost too late—after railway transportation had passed its peak. If the diesel-electric had come along earlier it might have been enough to offset some of the heavy competition of highway transporation. The effect now is largely to extend the life of a declining industry. No one has found a way to save our municipal electric transportation systems, and even the most versatile municipal bus systems seem to be having their difficulties. People want to ride in their own private cars. In the universal thirst for mobility we have so congested our streets and roads that in some places we have almost frozen ourselves into immobility. If taxicab companies in New York City were able to speed up their cabs to the rate of an unimpeded horse and buggy, they would find it profitable to pay an extra fifty cents a gallon of gasoline for the privilege. In this dilemma we can depend very little on development. We can only wait for capital invention.

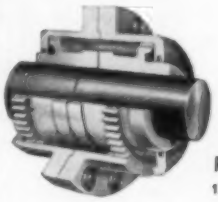
In the automotive industry there are some signs of a struggle to get out of the groove of classical internal-combustion technology. I refer to attempts to develop radical combustion chamber design, fluid injection, and gas turbine engines. These, also, are steps in the right direction. But when any of these developments are finally achieved for widespread use they will have arrived not before but *after* the petroleum industry has spent an extra billion dollars to match a fuel to classical engines. High octane fuel is almost at the peak of its growth curve, and the descent of this curve will be rather precipitous. We may expect from these developments only a moderate increase in miles per gallon, and because of excess of demand over supply the gallon will cost more. Some very new idea is required.

Questions that might occur to you are these: During the first half of the 20th century we have been moving forward in most technological categories with smoothness, precision, competence, and often brilliance. Except in the entertainment field we have experienced no sizable economic jolts through capital invention. Why should not such a serene prospect continue for the second half of the century? Why are so many technologists becoming suddenly restless? Why are so many radical estimates being made for the future?

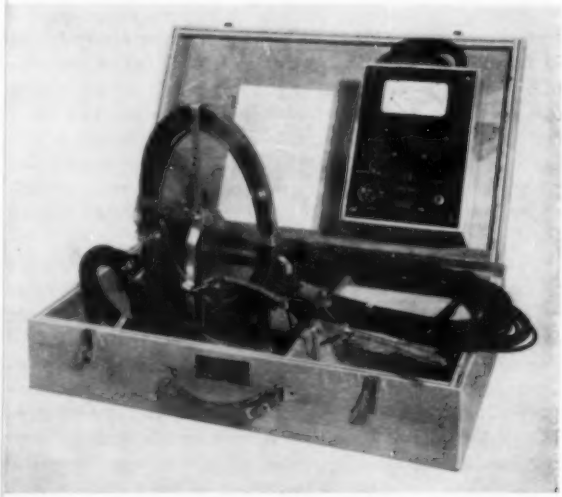
It seems to me that the answers to these questions lie in the newfound realization that the Age of Fossil Fuels is approaching—not its end, but its culmination. Ten years ago we centered our attention comfortably on the vastness of our fossil fuel reserves. It has been only during the past five years that we have learned how to interpret these magnitudes. The fact that the United States seems to have about 90 billion barrels of petroleum still to be produced does not mean that our peak of production can be later than 1965. The fact that the rest of the world is likely to produce about 1226 billion barrels of additional oil does not mean that the peak of production in the rest of the world is likely to be later than 1980. The fact that the United States may produce 600 trillion additional cubic feet of natural gas does not mean that the peak of natural gas production will come later than 1970. The fact that the United States seems to have nearly two trillion tons of coal yet to be mined does not mean that the peak of production of good coal at something like present costs will come later than about 1970. The coal story is complicated and interesting but cannot be expanded here. By way of illustration, 75 per cent of our coal reserve is made up of reserves that are merely inferred or are in beds thinner than 28 inches, or are more than 2000 feet beneath the surface. Of the other 25 per cent of our reserves, 80 per cent is more than 1000 feet deep. Of the 20 per cent of most accessible coal, 45 per cent is not bituminous. Of the most accessible bituminous only about half can be recovered by mining.

Taking Palmer C. Putnam's figures for total world reserves and for rate of the world's increase in energy demands, and assuming that nuclear fuels will not take over more than all electric power generation (now about 12 per cent of total energy demand) the world peak of production of all fossil fuels should come before the year 2000. At the peak, the world would probably want about 4×10^{16} Btu's per annum more than fossil fuels will provide, and world shortage would begin to take effect not later than 1975.

Never, since the beginning of the industrial revolution, have inventors had such an opportunity and such a challenge.



POOLE
FLEXIBLE COUPLINGS
ALL SIZES AND TYPES
CATALOG ON REQUEST
POOLE FOUNDRY & MACHINE CO.
1700 UNION AVE., BALTIMORE 11, MD.



STOP UNEXPECTED BOILER TUBE FAILURES

This completely new and improved model TURNER SCALE THICKNESS INDICATOR not only reads scale directly in thousandths of an inch, it is invaluable in locating pitted and eroded tubes prior to their failure, thus eliminating costly shutdowns. Write for technical data and information today.

HASKINS-TURNER COMPANY
1617 THIRD STREET JACKSON, MICHIGAN

Highlights of Nuclear Engineering and Science Congress—III

The safety aspects of water cooled and moderated reactors depend basically upon the inherent stability with respect to power transients of such reactors, according to **R. J. Creagan** of Westinghouse Electric Co. who presented a paper entitled "Safety Aspects of Water-Cooled and Moderated Reactors." In addition to the inherent stability, with respect to small power transients, any nuclear incident eventually is terminated by the expulsion of water from the reactor, with or without fuel element burnout.

Since the danger from such a reactor incident results from the distribution of radioactive fission fragments, the containment of these fission fragments is another safety item. In a typical water cooled power reactor the fission fragment containment is four-fold. The fission fragments are contained in the fuel which may be fissionable metal, an alloy, or a ceramic. The fissionable material is surrounded by a fuel element clad which provides the second barrier. A third barrier is provided by the pressure vessel and primary loop piping. The fourth and final barrier to expulsion of the fission fragments is provided by a vapor shield, which is a large volume pressure vessel which encloses the entire primary loop.

According to **E. P. Blizard** of Oak Ridge National Laboratory, who presented a paper entitled "Reactor Shielding," the shielding of nuclear reactors for stationary power plants is, in the large, an economical problem; feasibility is not in question. The economic considerations arise not only from the cost of the material involved but also from the size of the building which houses the reactor and ancillary equipment. The problems of shield design involve basically the specification of the thickness of concrete or other material which is required to enclose the reactor itself. Also to be considered is the shielding of external coolants, control rods, spent fuel elements, and other materials which have become radioactive inside the reactor and are subsequently removed. In addition to the shielding which is required for the biological protection of operating personnel, thermal shields next to the core must be incorporated to absorb most of the energy of the effluent radiations.

G. Hoyt Whipple of the University of Rochester, in a paper entitled "Radiation Hazard Control for a Power Reactor," stated that the maximum permissible occupational exposure recommended by the National Committee on Radiation Protection is 0.3 roentgen per week. The Committee makes it clear that the concept of a maximum permissible exposure does not entirely preclude the possibility of radiation injury to the exposed individual, or to succeeding generations. It is the intent, however, that the probability of the occurrence of such injuries should be so low that the risk will be readily acceptable to the average individual. In other words, a radiation dose of 0.3 r per week received week after week throughout a working lifetime is not without some risk. How great is this risk, and how does it compare with the ordinary risks of life?

For the purposes of this discussion, which is concerned with day-to-day exposures to small amounts of radiation, it will be sufficient to consider only two biological effects of radiation: life-span shortening and genetic mutations.

It has been found from extensive animal experimentation that repeated small doses of radiation reduce the life expectancy of the exposed individuals by an amount directly proportional to the total dose. It also appears from these experiments that the fractional life-span shortening per roentgen is relatively constant among the various species of animals, at about 1 per cent per 100 roentgens. It is important to note that individuals in the irradiated group die, in general, from the same causes as do the individuals in the control group; the difference is that they die a little sooner. It is impossible to assign radiation as the cause of death in any individual case.

The genetic mutations induced by radiation have given rise to considerable interest and some bitter controversy. The following statements, however, find general acceptance among geneticists. Radiation applied to the reproductive cells of living organisms will induce changes in the genetic material of these cells. The number of these changes is in direct proportion to the amount of the dose. Genetic changes of this sort are usually detrimental. It is not possible at present to predict the exact magnitude of the genetic risk involved in any given radiation exposure, but it is estimated that a dose between 100 and 200 r to every individual in one generation will double the mutation burden in the next generation.

The risk of genetic mutations is not to the individual who receives the radiation, but to his children and to succeeding generations. The problem of the genetic effects of occupational radiation exposure is one of conservation: conservation of the human race, if you will.

The control of irradiation hazard will add significantly to the total cost of buildings and operating a nuclear power plant. Consequently every item of control must be examined critically to determine whether it is essential to the proper operation of the plant, or whether it is justified on grounds of plant efficiency.

The cost of designed-in control and safety must be evaluated in terms of the savings they will permit in operating costs. Construction costs are paid only once, but operating costs will be paid throughout the life of the plant.

Suppose that a piece of equipment has failed in an area of high radiation levels, and that replacement of the equipment will require two man-hours of work in an area where the radiation level is 10 r per hour. Suppose also that the policy for special work conditions in the plant permits a man to receive up to 2 r in a single exposure, provided that he is removed from radiation exposure for a period of 13 weeks. Under these conditions the replacement job can be done with a minimum of 10 men, each receiving 2 r in a 12-minute work period. For the next 13 weeks these 10 men will be excluded from radiation work. If there is no radiation-free work in the plant for these men to do, the cost of the replacement job can be as high as $2^1/_2$ man-years.

The proper plant design is the one which reduces the frequency at which failures in high radiation areas will occur; it will reduce both the time and dose rates required to make these replacements; and finally, proper plant design will keep a large portion of the plant at sufficiently low radiation levels to permit radiation-free work by men who have received special work exposures.

Another economic aspect of radiation control which should be considered is legislation. Many states are considering legislation for the regulation of radioactive materials. Such legislation may not be desirable, but almost inevitably regulation and inspection in one form or another will be a part of nuclear power plant operation. Failure to take this into account in designing the plant may make the plant operation very cumbersome when such regulations are put into effect.

The recommended maximum permissible exposure of 0.3 r per week has a small but significant risk for a lifetime occupational exposure. It is strongly recommended that a figure no greater than one-tenth of this be taken as the criterion for a nuclear power plant. Proper regard for the control of radiation hazards in the plant design will reduce the risks to employees and will also reduce operating costs.

Radiation Effects

Two papers were presented on the subject of "Effects of Nuclear Reactor Radiations on Structural Materials." The one by **Ira F. Zartman** of the U. S. Atomic Energy Commission, Washington, D. C., stated that the need for neutron economy imposes the requirement of high purity for structural materials since many of the commonly tolerable impurities are good neutron absorbers. The materials must be free of such elements as boron, lithium, cadmium, and cobalt. The metal zirconium has many qualities which make it valuable in reactor construction; however, in nature the element hafnium is associated with zirconium. Since hafnium is a great neutron absorber, it must be removed and the zirconium prepared to a high degree of purity. This operation contributes considerably to the cost of reactor grade zirconium.

The radiation effects produced by reactor radiations may be grouped into three distinct categories, (a) capture processes, (b) ionization effects, and (c) atomic collisions.

Generally the physical property changes resulting from transmutations of elements following the capture of neutrons are relatively unimportant. A new element may be formed which may eventually play the role of an impurity atom. When neutron capture results in fission, as in fuel elements, large numbers of impurity atoms accumulate in the form of fission fragments, each fission producing two atoms. To the extent that impurities do not affect the physical or mechanical properties of materials the radiation effects resulting from this cause may be disregarded. In fuel elements this is not the case, and radiation damage is a serious problem.

In the second paper on the same subject, **J. C. Wilson** and **D. S. Billington** of Oak Ridge National Laboratory pointed out that in selecting structural materials for use in the high neutron flux regions of a nuclear reactor the engineer must consider several novel criteria that are peculiar to nuclear reactors:

(1) Materials with low neutron capture cross sections are preferred, because neutron capture by other than the fissionable fuel or breeding blanket lowers the reactor efficiency and will markedly reduce breeding gain or conversation ratio. Low neutron cross section per atom may be an inadequate criterion; neutron cross section per unit strength, or per unit corrosion resistance may have to be considered.

(2) Bulk heating resulting from the attenuation of gamma rays in the material, gradients in the bulk heating, and potentially high rates of bulk heating can give rise to thermal stresses and higher rates of applications of these stresses in reactor materials than have been commonly experienced in other structures. Gamma ray heating may exceed several watts per gram in high flux reactors, and reactor power changes by a factor of 100,000 in one second have been produced.

(3) Materials with high thermal neutron capture cross sections must be avoided where subsequent transmutations change the nature of the material by transmuting a critical alloying element to another element

ALL STAINLESS INTERNALS
eliminates corrosion of vital parts . . . specially designed to keep undeaerated water from contact with tank.

NO MOVING PARTS
completely self-adjusting at all loads without springs or mechanical gadgets . . . no clogging or sticking . . . no maintenance problems.

Send for FREE Bulletin 102

L·A

L ★ A WATER SOFTENER COMPANY
1007 Air Way Glendale 1, California

Are you getting what you pay for with YOUR coal dollar?

Before you contract for your 1956 coal supply, we suggest you make combustion comparisons. As you well know, actual steam cost—not coal price per ton—is the deciding cost factor. Let us demonstrate how to get all of the Btu content your coal dollar purchases.

At our Enos and Enoco Mines . . .

we ship over two million tons of exactly prepared coal annually to leading utilities and industries. Enos and Enoco coals are carefully screened, then blended to specific size requirements. *Controlled high quality, uniform size-consist* and *dependable delivery* insure top fuel economy.

If you are interested in fuel savings, our Combustion Engineers will gladly analyze your requirements. Their services are free of charge, and a test of either or both of these premium coals can be arranged. Their performance will be proof of their economy. Write or call today.

Place a trial order
Make a test comparison

THE ENOS COAL MINING COMPANY

Sales Offices for Enos and Enoco Coals

1405 Merchants Bank Bldg. Indianapolis 4, Indiana
310 S. Michigan Ave. Chicago 4, Illinois

You Can Be Sure of STRONGER REFRACTORY LININGS

after you apply

SUPER #3000 Refractory Bonding Cement

For Setting Fire Brick

Super #3000 has proved conclusively to be the strongest, most abrasion-resistant of all bonding mortars at low, medium and high temperatures to 3000° F.

It is volume-stable, expanding and contracting with the brick; hence it does not shrink or crack in the joints.

Because of its heavy body and water-retention properties, Super #3000 makes tight joints that prevent passage of gases into furnace walls. Used as a wash coat, it protects the firebrick against erosion.

On Inside Duct Lining

A ¾" thick layer of Super #3000 over the insulation provides long-life refractory lining that withstands erosion of hot abrasive gases.

On Induced Draft Fan Casings

Where previously repairs required heavy, abrasion-resistant steel plates, now a coating of Super #3000 provides safe protection for many months against the scouring action of fly ash. The same coating protection can be provided for dust collectors.

On Boiler Tubes

By painting the tubes (in the second and fourth pass of the boiler) with a thin mix of Super #3000, considerable protection is provided against erosion.

Super #3000, the truly all-purpose, ready-mixed bonding mortar that has proved its superiority on thousands of tough jobs, challenges your investigation. *Let us send you a drum for test.*

REFRACTORY & INSULATION CORP.

REFRACTORY BONDING AND CASTABLE CEMENTS
INSULATING BLOCK, BLANKETS AND CEMENTS

124 WALL STREET • NEW YORK 5, N. Y.

that is not metallurgically comparable. Otherwise very long exposures to high neutron fluxes may result in an alloy of different composition and properties.

(4) The material must be resistant to deleterious radiation effects. That is, energetic (fast) neutrons in a reactor have the ability to change the properties of a material by introducing vacant lattice sites, interstitially placed atoms, momentary high temperature regions (thermal spikes), or by breaking chemical bonds. Consequently many of the important engineering properties, or behavior characteristics, may be affected, some adversely.

Irradiation-induced mechanical property changes can be substantial and possible of sufficient magnitude to influence materials selection and design. Increased strength and hardness almost invariably result from neutron irradiation of metals if the temperature of irradiation or test is not so high that the radiation induced defects are annealed. Generally, annealing of the radiation effects in metals occurs substantially below the recrystallization temperature in engineering alloys.

The reduction of area and the elongation measured from tensile test specimens is usually reduced in irradiated metals. In some pure metals, and a few other age-hardenable or cold-worked alloys, irradiation may actually increase the elongation. Metals with low initial ductility seem to suffer greater reductions in ductility than materials of generally high ductility. Increased ductility, after irradiation, has been noted in two cold-worked aluminum alloys and in two age hardenable nickel alloys irradiated at 540 F.

Normalized carbon steels of the type used for pressure vessel construction suffer serious ductility loss after irradiation; in molybdenum alloys the same effect has been observed, but high purity iron loses little ductility after irradiation.

The austenitic stainless steels, the tougher nickel base alloys and a number of non-age hardenable aluminum alloys seem to lose very little ductility in irradiation, but there are examples of aluminum base and nickel base alloys, rather low in initial ductility, that have lost substantial amounts of ductility.

In considering the reduced ductility of the more ductile metals it must be remembered that simultaneously an increase in yield and ultimate strength accompanies the loss in ductility in the irradiated metals. If two reasonably ductile annealed metals are brought to the same yield stress level, one by cold work, the other by irradiation, it will usually be found that the elongation and reduction of area are greater for the irradiated metal, but the ultimate strength of the cold worked metal may be greater or less than the irradiated metal.

Liquid Metal Systems

Liquid metals for heat transfer purposes lie in an area of technology whose development has been greatly accelerated by widespread interest in atomic energy. Very substantial development funds have been made available to the several AEC laboratories and private companies engaged in applying liquid metals in heat exchangers.

In a paper entitled "Selection of Materials, Design, and Specialized Fabrication Procedures for Sodium and Sodium-Potassium Cooled Heat Transfer Systems," **W. L. Fleischmann** and **R. F. Koenig** of the General Electric Co. stated that the principal advantage of a liquid metal, specifically sodium, over water is its high boiling point. That means that sodium can be maintained as a liquid to extremely high temperatures without pressurizing the systems. At the same time, the melting point of sodium is rather low. High rates of heat transfer are obtained at reasonable fluid flow rates, and the low viscosity of sodium makes the pumping power requirements reasonable.

Since sodium and NaK are metals, it is important to recognize that heat is conducted not only by molecular momentum and eddy diffusion as in gases, organic liquids, and water, but also by electron motion, a mechanism which is equivalent to conduction of electricity. Hence, one of the significant characteristics of the liquid metals is their high thermal conductivity. Because of the high thermal conductivity, analogous to electrical conductivity, heat is readily conducted through narrow channels without the necessity of depending upon convection or eddy current diffusion.

This combination of high thermal conductivity, high specific heat, and low density makes the alkali metals appear desirable for liquid metal heat transfer systems. Their superiority is particularly marked in heat transfer systems having high thermal fluxes. In a nuclear reactor the allowable heat generated by the fuel elements is only limited by the ability of the coolant to remove the heat, and hence for this application the alkali metals have a distinct advantage.

Modern Design *for the*

MODERN COAL

The Fairmont Coal Bureau has made available to consulting engineers and equipment manufacturers a TYPICAL DESIGN for the small industrial steam plant. Prepared as a guide to good engineering it achieves maximum economy of investment and engineering costs, while featuring:

- Fuel flexibility
- High efficiency
- Low fuel costs
- Minimum labor requirements
- Cleanliness, Automaticity, Reliability

Fairmont Pittsburgh Seam Coal is the MODERN COAL. Enormous reserves and inherently favorably mining conditions guarantee ample supply and low production cost. Modern mining and preparation facilities assure uniform quality.

Fairmont Coal Bureau engineers are freely available to help you solve fuel and combustion problems. Write for Technical Reference Bulletins and other valuable publications.

FAIRMONT COAL BUREAU

Dept. DC, 122 East 42nd St., New York 17, N. Y.

According to **O. E. Dwyer, D. H. Gurinsky,** and **J. R. Weeks** of Brookhaven National Laboratory, in a paper entitled "Liquid Bismuth As a Fuel Solvent and Heat Transport Medium for Nuclear Reactors," bismuth has the advantage of a very low cross section for neutron absorption, low chemical reactivity, and good heat transfer-transport characteristics as a primary coolant for thermal nuclear reactors. It is also a sufficiently good solvent for uranium to make it the only practical carrier for a liquid-metal fuel. On the debit side, bismuth has relatively high pumping power requirements, presents a corrosion problem, has a high cost, and produces Po-210 upon neutron irradiation.

Bismuth is not a plentiful element. During the last war, its production in this country reached about 1000 tons a year, wholly as a by-product of the refining of lead and copper ores. Its present market price is $2.25 per lb in ton lots, or at 450 C this amounts to $1380 per cu ft. These figures compare with $0.17 and $8.92 respectively, for sodium. There is good reason to believe that, should a sufficient demand for bismuth develop, production could be substantially increased without an appreciable increase in price and possibly with a decrease.

New Books

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N.Y.

Technical Writing

By G. H. Mills and J. A. Walter

Rinehart & Company, 463 pages, $4.50

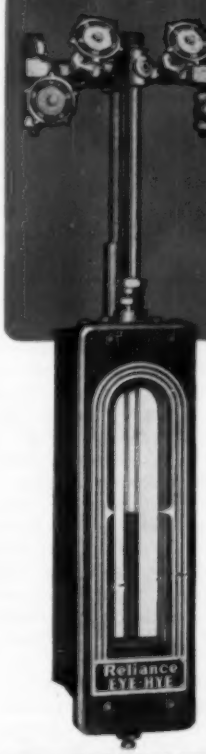
The Technical Report

Edited by B. H. Weil

Reinhold Publishing Corp., 485 pages, $12.00

Foundations for technical writing are established in the grade school through the mastery of reading and grammar. Effective technical writing based upon these foundations is a product of further training at the high school and college levels and continued self-development on the part of the engineer. "Technical Writing" concerns itself primarily with the principles and practice of writing as it might be taught at the college level. Complementing and supplementing the foregoing is "The Technical Report—Its Preparation, Processing the Use in Industry and Government" which is an extremely useful compilation of material (much of which was previously unavailable in one source) for the graduate engineer, in-

Check your boiler water levels with the completely hydrostatic Reliance EYE-HYE Remote Reading Gage

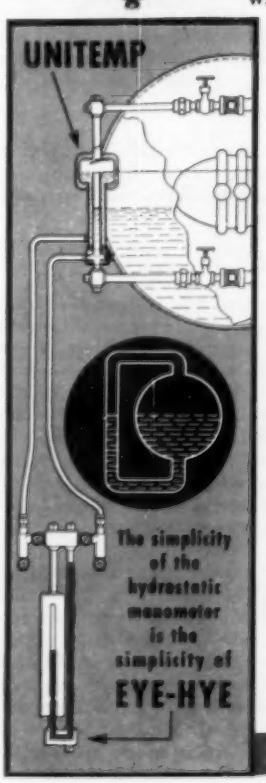


Simple as A-B-C, yet accurate, safe, dependable

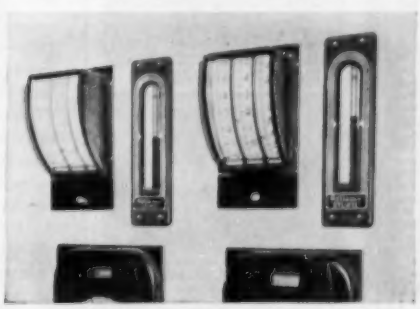
Make your boilers and power plant safer from water level failure. Use an EYE-HYE on each boiler. Engineers can't miss seeing this reliable, accurate device that carries water level reading to panel or convenient wall position.

Simplicity is the secret of EYE-HYE's dependable full-range accuracy — all hydrostatic operation, no mechanical working parts. Factory-calibrated to your water level range and working steam pressure — cannot be tampered with. Nothing to adjust during installation. Easy to install, practically no maintenance. Complete "Unitemp" temperature equalizing unit is furnished with each EYE-HYE.

Reliance EYE-HYE is a familiar sight in thousands of power plants. Models for any remote gage need — any pressure. Write the factory or nearest Reliance Representative for Bulletin CO.



The Reliance Gauge Column Company
5902 Carnegie Avenue • Cleveland 3, Ohio



Reliance
BOILER SAFETY DEVICES

cluding editors and technical writing specialists.

The text by Professor Mills and Professor Walter of the University of Texas is especially valuable because of the large number of excerpts published from actual reports. In most instances the authors have prepared a commentary analyzing the reports and pointing out the application or misapplication of specific writing techniques. Possibly a third of the book is devoted to these examples of technical writing, including a major appendix in which four manuscripts (two oral and two written, on the same subject) by John L. Galt are published.

The engineer who is interested in seeing how preparation of a manuscript for oral presentation differs from that for formal publication will find the Galt manuscripts quite revealing. In fact, they might be made required reading for those who are preparing papers for submission to professional societies. If more engineers would take the same kind of trouble to prepare oral and written versions of their technical papers, quality standards at engineering society meetings would rise appreciably. And perhaps equally important, the all-too-prevalent technique of monotone reading of dull technical material, scarcely a credit to a child in grade school, might be superseded by a more vibrant oral presentation that would maintain audience interest in even the most abstruse technical subject.

In contrast to the educational approach used in "Technical Writing," B. H. Weil, who is Manager of Information Services of the Research and Engineering Department of Ethyl Corporation, combined the talents of 23 contributing authors in editing "The Technical Report." The book is the outcome of a symposium which the Division of Chemical Literature of the American Chemical Society conducted in 1953. The result is a very comprehensive coverage of current practices in writing, illustrating, editing, duplicating, filing, retrieving and using technical reports.

The five parts of the book are entitled, respectively, functions, preparing and processing, distributing, filing and using. Distinctions are made between the functions of the technical report in industry and in government. Information is provided on the writing of progress reports, formal reports, literature summaries, and oral reports. Several interesting chapters deal with methods of indexing, classifying, filing and abstracting technical reports. There is also considerable information on methods of illustrating, duplicating and binding reports.

Anyone whose responsibilities include the preparation of technical reports will find this book of very considerable value. It certainly belongs in every industrial library, and it may well serve as a writing handbook for individual engineers as well.

ERNST
HIGH PRESSURE
GLASSES
and GASKETS
All sizes to fit your gages and valves
MAGNIFYING RED LINE

FIG. 22 SERIES 750

FIG. 21 LIP-MOLD
STATE YOUR REQUIREMENTS
All shipments from stock.
Send for Catalog
ERNST WATER COLUMN & GAGE CO.
Livingston 6-1400 LIVINGSTON, N. J.

Symposium on Effect of Cyclic Heating and Stressing on Metals at Elevated Temperatures

ASTM Special Technical Publication No. 165, 184 pages, $3.00

It has been long realized that much, if not most, engineering use of metals at elevated temperature involves periodic changes in temperature or stress or both. However, the engineer has available for most metals only constant stress and temperature data for design purposes. This poses the question of how changes in stress or temperature modify the constant stress and temperature behavior of metals and thus the designs based on such behaviors.

This Symposium, which was originally presented at the 1954 ASTM Annual Meeting, is intended to cover those situations involving relatively slow changes in stress or temperature or both. In practice many such changes are aperiodic, and much of the experimental work covering this Symposium uses periodic variations. It is hoped that certain general considerations may, however, be deduced from the experimental results herein.

The information in this Symposium should be of use both to the engineer-designer, as an aid in designing for stress or temperature variation, and to the researcher as a spur to greater efforts to obtain more exact data or design criteria.

Report on the Elevated Temperature Properties of Selected Super-Strength Alloys

ASTM, 208 pages, $4.75

This is the third in a current series of reports prepared under the auspices of the Data and Publications Panel of the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals.

Primarily this report is a graphic summary of the elevated-temperature strength data for 13 selected super-strength alloys. Included are 116 summary curves showing tensile strength; 0.2 per cent offset yield strength; per cent elongation and reduction of area; stresses for rupture in 100, 1000, 10,000 and 100,000 hr when available; and stresses for creep rates of 1 per cent in 10,000 and 100,000 hr.

Original data sheets (206 of them) appear in the body of the report directly following the curves. A brief description of each alloy is included which gives chemical composition, recommended heat treatment, and a few words about forging and machining. These alloy descriptions furnish the reader with a basis of comparison so that he can refer to the optimum processing conditions recommended by the producer of each alloy when using the data. It is not intended that these brief descriptions serve as a guide for using the alloys in production as complete information is available from the alloy producers upon request.

The Appendix contains some very-short-time rupture data for several of the alloys, and a compilation of chemical compositions for approximately 100 super-strength alloys.

The following alloys are covered by the data:

19-9DL	Haynes Alloy No. 25
16-25-6	Refractaloy 26
Discaloy 24	Inconel "X"
A-286	M-252
N-155	Haynes Alloy No. 21
S-590	Haynes Alloy No. 31
S-816	

ASTM Standards on Coal and Coke (with Related Information)

ASTM, 164 pages, $2.25

Twenty-seven methods of test, defini-

tions, and specifications for coal and coke and the standard specification for the classification of coal according to rank and grade are included in the 1954 edition of the Standards. This compilation in its previous editions has been widely accepted and used by the coal and coke industry and by industries and agencies purchasing these fuels in carload or greater lots. It is of particular use to electric utilities companies with coal fired steam generating plants, coke and gas manufacturers, governmental agencies and others which buy coal and coke in large quantities on specification.

The standards have been prepared by Committee D-5 on Coal and Coke of the American Society for Testing Materials. The Society is the recognized American agency for standardization of methods of sampling and test methods for coal and coke. Some of the standards contained in the compilation also have been approved as American Standards by the American Standards Association as indicated by symbols at the top of the title pages.

In addition to the standards, eight appendices give proposed methods of test which are published in draft form for the purpose of soliciting comments.

Symposium on Coal Sampling

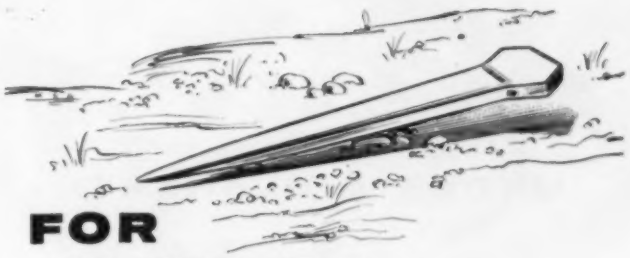
ASTM Special Technical Publication No. 162, 156 pages, $2.75

This is the most significant symposium on coal sampling that has occurred in the past ten years. It was sponsored by ASTM Committee D-5 on Coal and Coke at the 1954 Annual Meeting of the Society. The authors represent both companies utilizing coal and organizations studying the statistical problems of coal sampling, both here and abroad.

In the early 1930's ASTM Committee D-5 appointed a subcommittee on coal sampling whose early work was devoted to mechanical sampling. As the work of this group progressed it was realized that the existing theories on the subject of coal sampling were controversial, and that data on mechanically sampled coal were almost nonexistent insofar as these data would be of any value toward resolving the theory of the problem of writing a standard sampling procedure. Hence, it was decided that a series of experiments should be undertaken to collect data that could be applied to the problem.

Inasmuch as an expenditure of approximately $50,000 was required for the performance of these experiments, the committee decided that the results should be made available in one informative source to anyone interested in the work. A symposium seemed the best means to implement this decision.

200-1



FOR WANT OF A NAIL...

Something that wasn't there once cost a king his life.

For today's boiler, lack of internal protective surfacing is hardly a life or death matter. Yet consulting engineers . . . insurance underwriters . . . power plant operators increasingly specify, recommend, and purchase Apexior Number 1 for tube and drum coating. Why?

Because the yardstick of return on investment proves Apexior's unique service *now pays off at the highest rate ever* . . . for modern boiler design and operation today permit a single Apexior application to deliver maximum protection not only for a normally anticipated five years, but for one — three — sometimes even *five years more!*

And because Apexiorizing is now a one-coat procedure, former material and labor estimates are halved. Protection that can last twice as long today costs *half as much* . . . a trifling pennies-per-square-foot premium to insure full return on a major capital investment.

Like the legendary nail, boiler protective coating may seem a factor of small significance — yet it can mean the difference between acceptable performance and the best of which the modern boiler is capable. The assurance every inspection gives that tubes and drums are functioning at new-metal peak efficiency is the measure of Apexior's service in maintaining highest steam production reliability and quality — a contribution measured ultimately in profit dollars.

Internal boiler protection is but one phase of Dampney corrosion-control activity. Dampney Coating Systems for specified end-use service protect cooling towers — intake water structures — pipeline interiors. For a recommendation to meet your requirements, write

MAINTENANCE FOR METAL

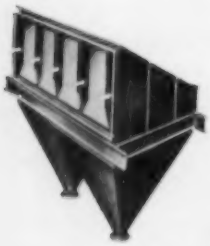
THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

Your plant and equipment suffers . . . your community goodwill fades away. These problems can be solved. Prat-Daniel Collectors are designed for the control of industrial dusts and flyash. Multiple small diameter tubes provide powerful centrifugal forces, resulting in sustained high collection efficiency . . . even with ultra-fine dusts.

Whether the problem is industrial dust or flyash, you are assured of satisfaction with P-D Collector Systems, engineered to meet your specific needs.

Write for Reprint No. 102 titled, "What Type Collector?"



pd

Project Engineers
THE THERMIX CORPORATION
GREENWICH, CONN.
(Offices in 38 Principal Cities)
Canadian Affiliates: T. C. CHOWN, LTD., Montreal 25, Que.

Designers and Manufacturers
PRAT-DANIEL CORPORATION
SOUTH NORWALK, CONN.
POWER DIVISION: Tubular Dust Collectors, Forced Draft Fans, Air Preheaters, Induced Draft Fans, Fan Stacks

ASTM Manual on Industrial Water

ASTM, 430 pages, $5.00

This Manual, revised and reprinted in 1954, offers a broad discussion on the nature and uses of industrial water, plus up-to-date test methods and specifications developed by leading authorities in the field.

While the general discussion, comprising the eight chapters in the front of the book, is essentially identical to the first printing, 11 new test methods, 8 revisions of existing methods, a complete table of contents, and a detailed index have been incorporated into the Manual. Also several proposed methods published as information have been included.

This Manual was prepared by Committee D-19 of the American Society for Testing Materials.

Chapters include the following information:

I. Uses of Industrial Water
II. Difficulties Caused by Water in Industry
III. Composition of Industrial Water and Water-Formed Deposits
IV. Treatment of Industrial Water
V. Sampling of Industrial Water
VI. Analysis of Industrial Water
VII. Sampling and Identification of Water-Formed Deposits
VIII. Analysis of Water-Formed Deposits

Included in this Manual are the various specifications, sampling methods definitions, and test methods that have been standardized by the Society through the work of its Committee D-19. Methods are listed for: sampling; analysis; reporting results; and testing.

New material includes 10 methods for: chemical oxygen demand (dichromate oxygen demand) of industrial waste water; chlorine requirement of industrial water and industrial waste water; in industrial water (residual chlorine-nitrate ion-sulfite ion); in industrial waste water (odor-oil matter-pH-sulfides); also determination of thickness of internal deposits on tabular heat exchange surfaces; and 1 scheme for analysis of industrial water and industrial waste water.

This Manual is intended as an authoritative reference source of information

for three types of users: executives and plant designers; individuals engaged in industrial operations involving the use of water; and analysts, operators of special instruments, engineers, and consultants.

ASTM Specifications for Steel Piping Materials

ASTM, 432 pages, $4.00

The 1955 edition of this compilation sponsored by ASTM Committee A-1 on Steel contains the latest approved form of 58 ASTM specifications for ferrous pipe, tubes, castings, fittings, and bolting materials.

Included in these standards, 47 of which have been revised this year, are Tentative Methods and Definitions for Mechanical Testing of Steel Products (A 370), and Classification of Austenite Grain Size in Steels (E 19). Also included in the compilation are American Standards for Wrought Steel and Wrought Iron Pipe (B 36.10) and Stainless Steel Pipe (B 36.19).

New specifications not in the 1954 issue include specifications for:

- Metal Arc Welded Steel Pipe for High Pressure Transmission Service (A 381),
- Cold Drawn Wrought Iron Heat Exchanger and Condenser Tubes (A 382),
- Alloy Steel Castings, Normalized and Drawn for High Pressure and Elevated Temperature Service (A 389).

The specifications by virtue of their having been developed by Committee A-1 on Steel comprising prominent authorities representing consumers, producers, and general interest members, are in wide-spread use. As a result this book is of a distinct service to those concerned with pressure piping, power generating, the petroleum field, and in fact all industries where the proper selection of these types of ferrous metals is essential.

WANTED
POWER ENGINEER

Heavy chemicals plant, Upper Ohio Valley, is seeking top notch Mechanical or Electrical Engineers with 2-4 years' power operating experience. Would join organization operating 55,000 Kw multi-unit coal-fired station. Opportunities for good men in a fast-growing plant.

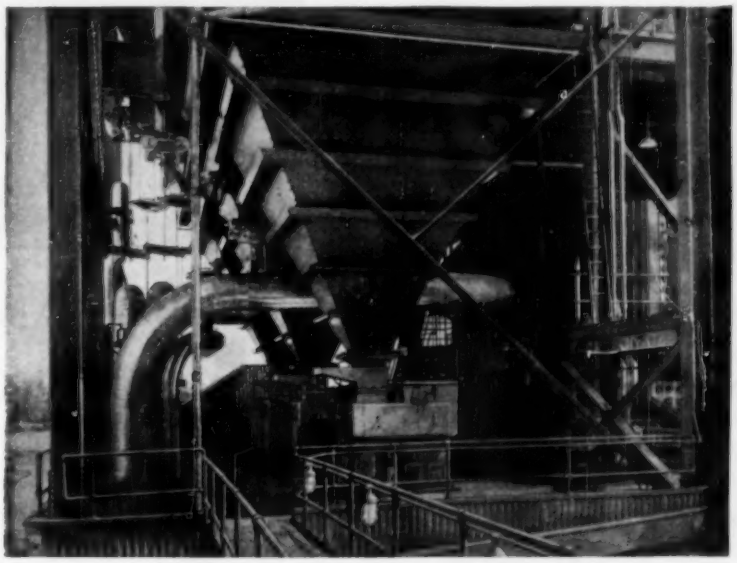
Address inquiries in care of Combustion Publishing Co., Inc., Box 700, 200 Madison Ave., New York 16, N. Y.

Carolina Power & Light

again specifies

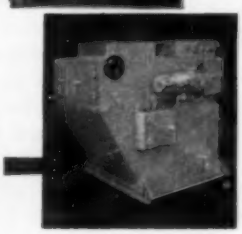
Richardson

Richardson Automatic Coal Scales are playing a vital part in helping supply power for the new Industrial South. Here are Richardson Model 39's in an outdoor installation at the new generating station of Carolina Power and Light.



To both industrial and utility power generating stations, specifying Richardson means—

1. A 24" x 24" inlet opening and 26" wide belt for maximum coal flowability.
2. All wiring and controls outside coal chamber.
3. Access doors which will not spill dust on floor when opened.
4. Beam ratio test facilities outside coal chamber.
5. Gravity operated by-pass, with no restriction of coal flow to downspout.
6. No drag links or wires attached to weigh hopper.
7. Nationwide after-delivery service.



Latest development in the 39 Series of Richardson Automatic Coal Scales is the Model H-39 shown below. May we send you our new 16-page engineering data book on the H-39 Coal Scale (Bulletin 0352), without cost or obligation?

RICHARDSON SCALE COMPANY · Clifton, New Jersey

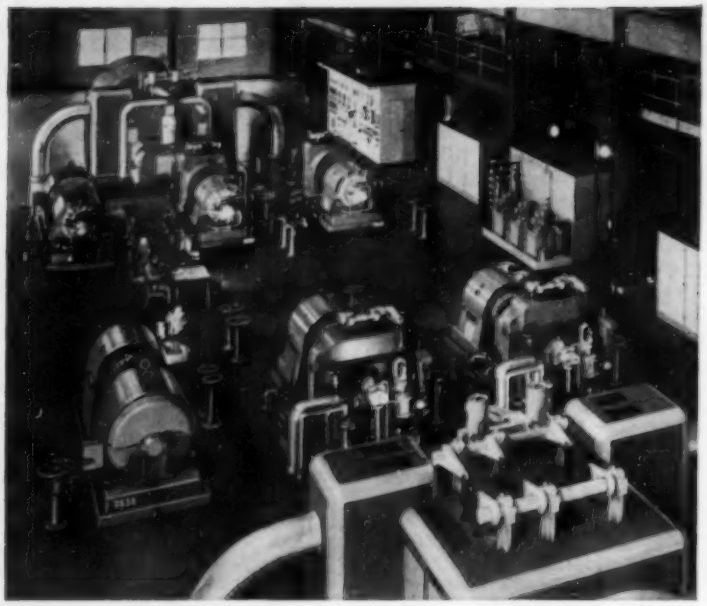
Atlanta • Buffalo • Boston • Chicago • Detroit • Houston
Minneapolis • New York • Omaha • Philadelphia • Pittsburgh
San Francisco • Wichita • Montreal • Toronto

0761

Richardson

MATERIALS HANDLING BY WEIGHT SINCE 1902

What makes a barrel-type boiler feed pump *stay in service?*



Here are some of the design features that assure dependability

Today's modern multi-stage centrifugal pumps for boiler feed service are the result of years of research and design. To provide efficient service *plus* dependability, De Laval has incorporated these important features in its barrel-type pump.

Double Volute Diaphragms

Double volute diaphragms provide for radial hydraulic balance and assure a continuous rising head characteristic from the design point to shut-off. *RESULT—Higher efficiencies are maintained over a wider range of operation than are generally obtained with other forms of velocity pressure conversion.*

Individual Diaphragm Bolting

Elimination of rabbet fits and gaskets permits straight metal-to-metal contact of adjacent lapped faces of the diaphragms which are individually bolted together to maintain tight joints and ease of assembly. *RESULT—Positive assurance against inner case leakage, complete elimination of misalignment causes and a minimum of distortion from sudden temperature changes.*

Positive Sealing Between Suction and Discharge Chamber

Inner assembly is held at the inner high pressure joint at the suction end of the barrel, against a flexitallic gasket, with through bolts. The joint between the suction and discharge chambers is made tight during assembly—remains tight whether pump is operating or idle. *RESULT—No possibility of leakage or gasket loosening due to changes of force on the inner joint.*

Bare Shaft

Bare shaft construction with split ring-shrink fit method of impeller mounting permits a scalloped shaft design and eliminates the need for spacer sleeves between impellers. *RESULT—Better hydraulic conditions at the eye of the impeller and elimination of spacer sleeves—the greatest cause of shaft warpage.*

Wearing Rings

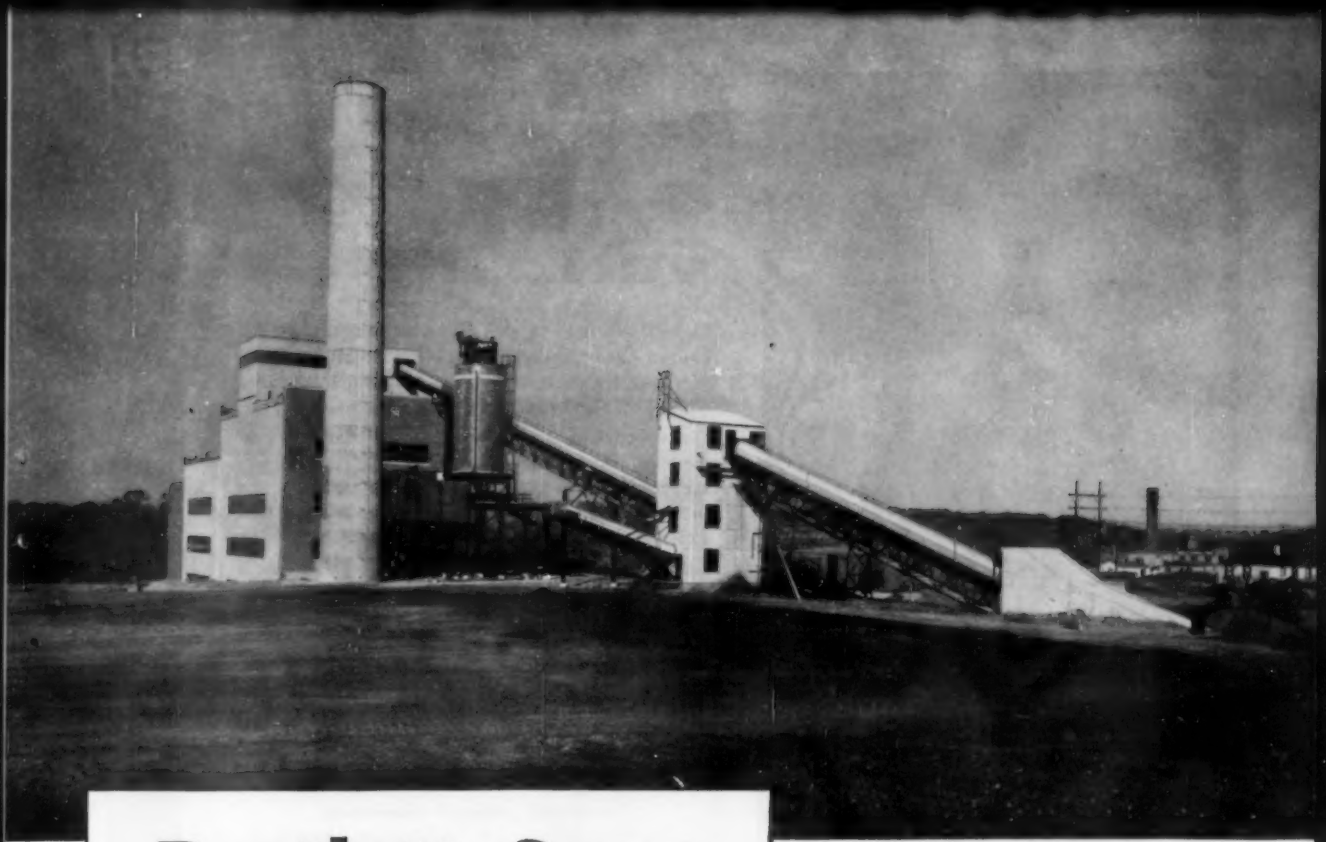
Diaphragms and impellers have renewable wearing rings. Impeller rings are threaded on the impeller hubs against rotation, and diaphragm rings are held by a breech lock fit in the diaphragms. *RESULT—Construction permits renewal of original clearances without major part renewal or modification. Labyrinth type diaphragm ring results in minimum leakage over a longer period of time than with close clearance flat rings.*

IMO Oil Pump

A De Laval IMO pump designed for high speed operation is direct-connected to the outboard end of the barrel pump shaft, and is sized to lubricate both pump and driver bearings. *RESULT—Quiet, pulsation-free, positive displacement IMO pumps, assures positive lubrication and eliminates the need of extra shaft length and mechanical complications required by gear drive lube oil pumps.*

BULLETIN CONTAINS HELPFUL DATA

This De Laval bulletin on the barrel-type boiler feed pump covers all major design points . . . has cross-section cut-away illustration for easy reference. Write on your business letterhead for your copy of Bulletin 1506 to De Laval Steam Turbine Company, 886 Nottingham Way, Trenton 2, New Jersey.



Bartlett-Snow coal handling at Rockford

● The illustration above shows the first 30,000 KW unit of a plant which is to be extended into a 110,000 KW station. All coal handling equipment including track hopper and grill, duplex feeder, conveyors, galleries, chutes, tripper and all supporting structures were fabricated in our shops, and installed by us, to Stone and Webster's plans. For efficiency, satisfaction, and fixed unit responsibility, let the Bartlett-Snow coal handling engineers, with their long experience and complete facilities work with you on your next job.

DESIGNERS
ENGINEERS

BARTLETT-SNOW
CLEVELAND 5, OHIO

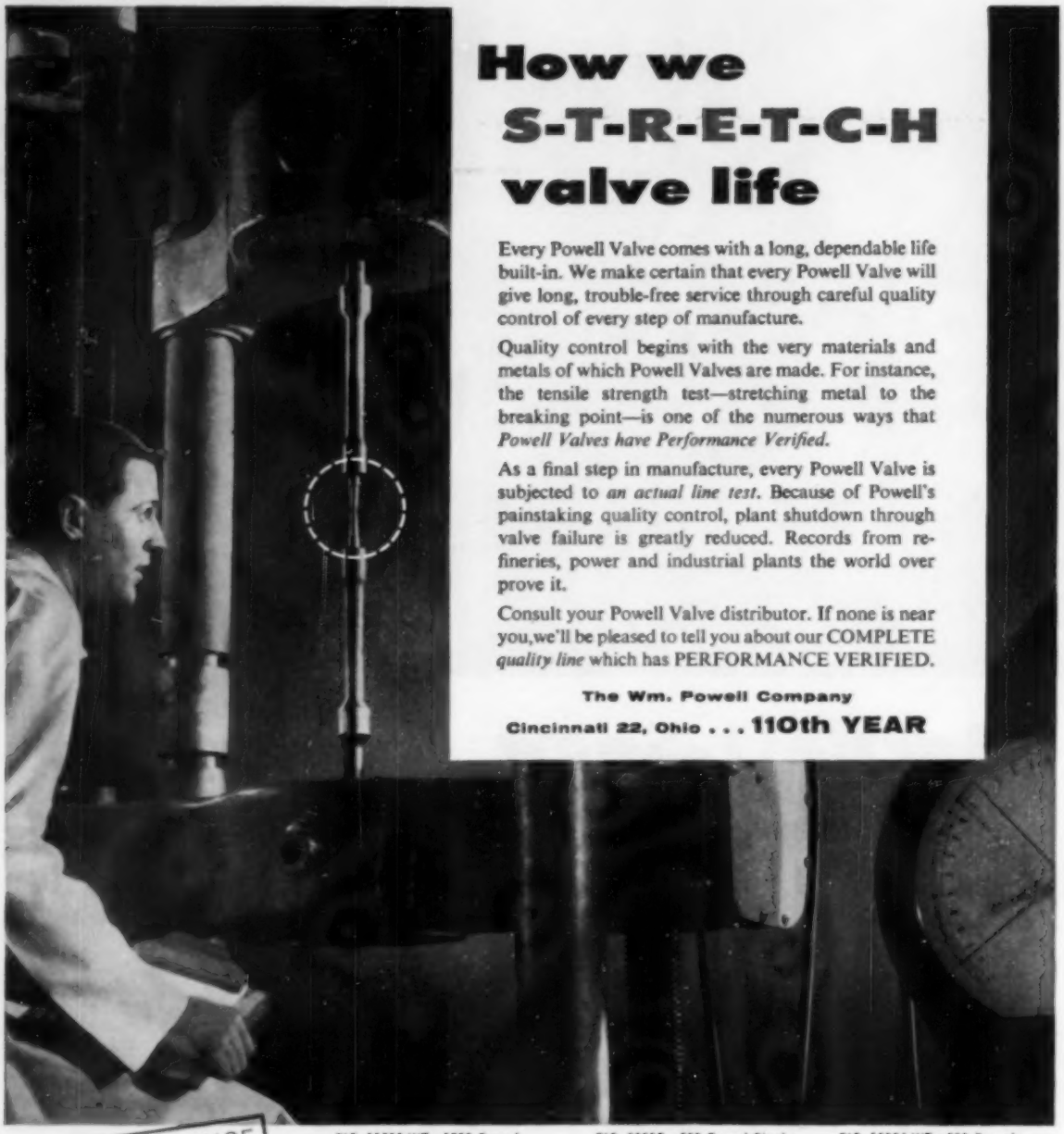
FABRICATORS
ERECTORS

"Builders of Equipment for People You Know"

General View—Saybrooke Station
Central Illinois Elec. & Gas Co.
Stone and Webster Eng. Corp.
Consulting Engineers

Belt Conveyor from
Track Hopper to Crusher House

View of Crusher House and
Stacking Out Conveyor



How we S-T-R-E-T-C-H valve life

Every Powell Valve comes with a long, dependable life built-in. We make certain that every Powell Valve will give long, trouble-free service through careful quality control of every step of manufacture.

Quality control begins with the very materials and metals of which Powell Valves are made. For instance, the tensile strength test—stretching metal to the breaking point—is one of the numerous ways that *Powell Valves have Performance Verified.*

As a final step in manufacture, every Powell Valve is subjected to *an actual line test.* Because of Powell's painstaking quality control, plant shutdown through valve failure is greatly reduced. Records from refineries, power and industrial plants the world over prove it.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our COMPLETE *quality line* which has PERFORMANCE VERIFIED.

The Wm. Powell Company

Cincinnati 22, Ohio . . . 110th YEAR

PERFORMANCE PV VERIFIED

FIG. 11303 WE—1500-Pound Pressure Seal Steel Gate Valve.

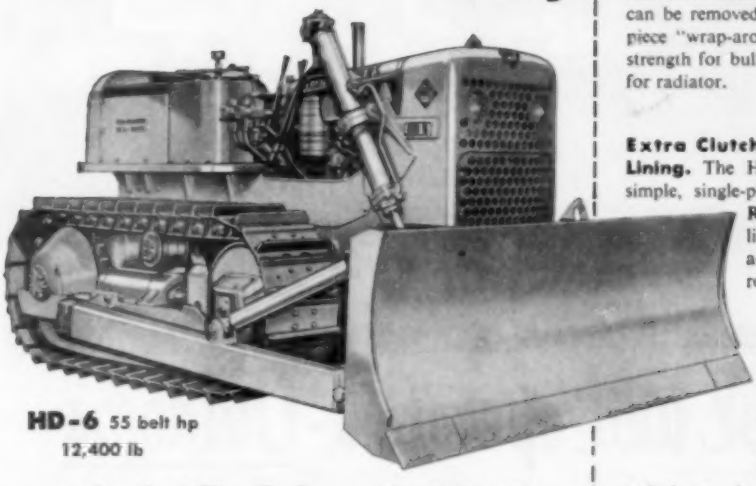
FIG. 3059G—300-Pound Steel Lubricated Plug Valve. Gear Operated. Sizes 6" to 12".

FIG. 19084 WE—900-Pound Pressure Seal Non-Return Globe Valve. Gear Operated.

POWELL VALVES

BRONZE, IRON, STEEL AND CORROSION RESISTANT VALVES.

This kind of Crawler Tractor Design gives you extra coal-handling ability



HD-6 55 belt hp
12,400 lb

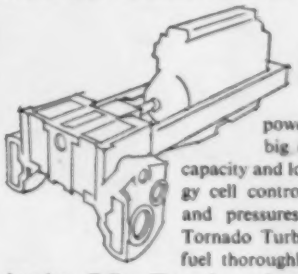
. . . and only Allis-Chalmers HD-6 has it—

advanced design features that combine big performance, versatility, dependability and simplified servicing!

Look at the Allis-Chalmers HD-6—you can see its functional design . . . how it's built to give sure-footed traction, better working balance. But there's more to this crawler tractor than meets the eye—the performance advantages of Allis-Chalmers advanced basic design. It provides more working power, more strength in all components, more working weight where it's needed . . . makes the HD-6 an outstanding performer with drawn or mounted equipment . . . easier to operate and maintain.

Let your Allis-Chalmers dealer show you how the HD-6 can give you that *extra* output on your jobs.

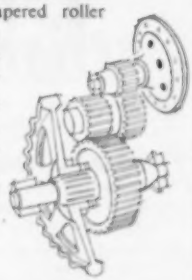
ALLIS-CHALMERS, CONSTRUCTION MACHINERY DIVISION
MILWAUKEE 1, WISCONSIN



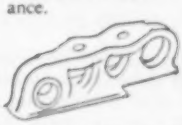
Allis-Chalmers Heavy-Duty Diesel Engine. The HD-6 power plant is designed for big output, ample reserve capacity and low maintenance. Energy cell controls combustion timing and pressures for high efficiency. Tornado Turbulence mixes air and fuel thoroughly for more complete burning. Follow-Through combustion sustains effective working pressures to take advantage of better crankshaft leverage.

Special Strength and Protection. Exclusive all-steel box-A main frame makes possible superior over-all balance, better equipment mounting . . . plus service simplicity of unit construction. Major assemblies like engine and clutch can be removed without disturbing adjacent parts. One-piece "wrap-around" radiator guard provides maximum strength for bulldozer mounting . . . complete protection for radiator.

Extra Clutch Life—with Ceramic Lining. The HD-6 master clutch offers simple, single-plate, over-center design. Revolutionary new ceramic button clutch lining keeps clutch operating longer between adjustments . . . lengthens clutch life . . . reduces lever pull for easier operation.



Straddle-Mounted Final Drive Gears. Tapered roller bearings support both ends of the final drive gear shafts. Smaller gears and shorter shafts (plus line-bored, one-piece case), provide better bearing and gear alignment, more strength, longer life. Double-reduction final drives provide greater ground clearance.

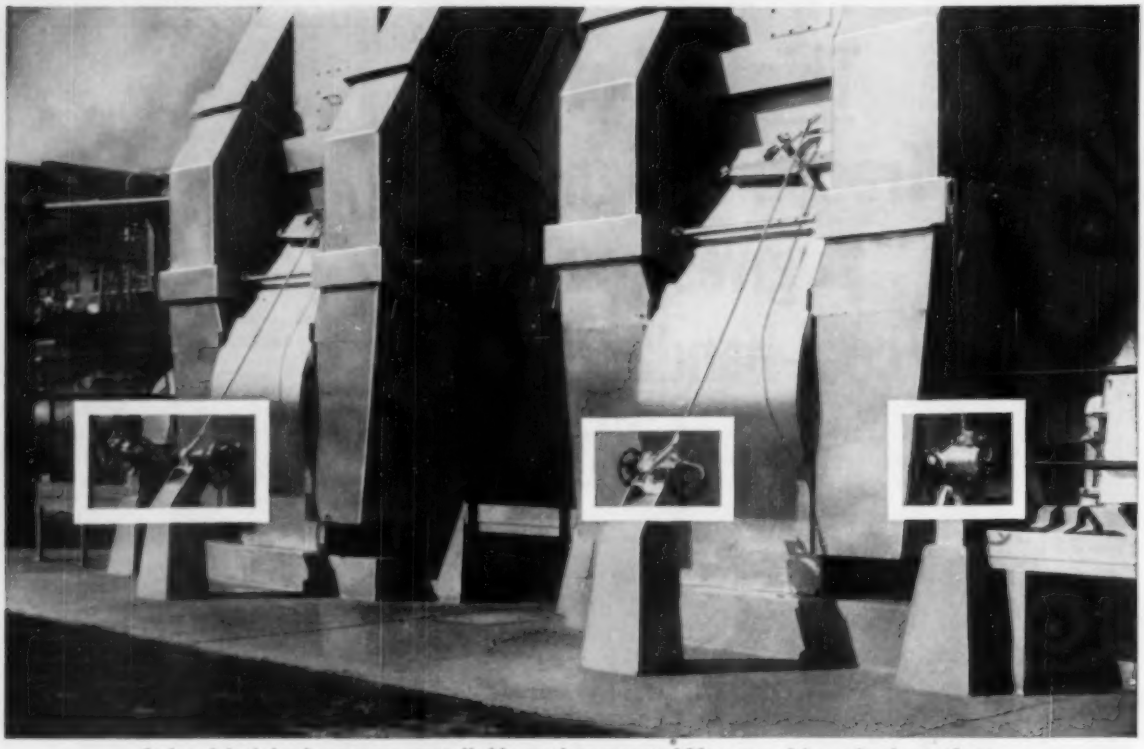


New-Design, Heavy-Duty Track. HD-6 track provides long life under the toughest conditions. HD-6 sidebars have more steel where it's needed . . . benefit from new heat-treating methods which make possible new standards of strength and hardness throughout for extra wearability.

Other Outstanding HD-6 Features

. . . no other tractor in this size class has them—at no extra cost you get roller bearing truck wheels, idlers and support rollers; 1,000-hour lubrication intervals for truck wheels, idlers and support rollers; 24-volt direct electric starting; crankcase guard; bumper; and lights.

ALLIS-CHALMERS



Induced draft fan louvers are controlled by outdoor-mounted Metermax drive units shown above.

HERE'S HOW TO GET

reliable drive unit operation-Outdoors

Metermax Electric Drive Units operate in outdoor locations in spite of snow, sleet, driving rain, and summer sun. They position fan louvers, vanes, dampers, mill feeders, or any other controlled element. And they never quit as long as you give them power.

There's no need for expensive air dryers, jackets, or weather shelters; the units drive in any kind of weather—BARE—and give you continuous, accurate positioning.

At all times, electric drive units provide the instant response necessary for closely coordinated action in large central stations where controlled elements are widely separated.

As for dependability—these drive units operate for long periods with only routine lubrication. Many have been in continuous service—indoors and outdoors—for more than 15 years.

These specific features may interest you:

Self-locking double worm-and-gear drive. *There's no chance of trouble from backdriving. And no locking devices are needed.*

Self-releasing effect of worm-and-gear *permits resumption of remote manual control immediately on restoration of power . . . you don't have to unlock or reset the individual units.*

Simple remote control. *You transfer quickly from automatic to remote manual control by simply turning the control station handle; there's no reset fuss to bother with.*

Compact, functional control station arrangement. *Because the electric control stations require no piping, a close, functional grouping with other motor controls is possible without losing back-of-panel accessibility.*

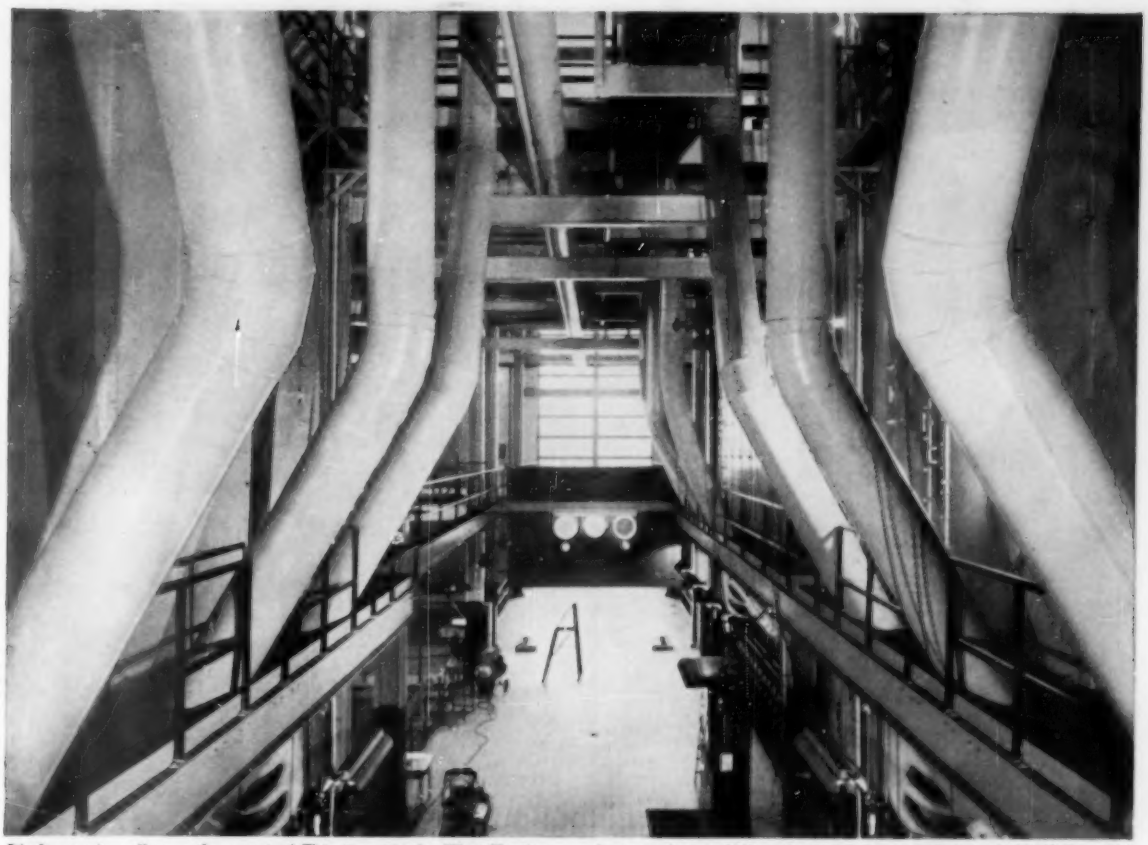
True position indication. *You always know precisely the position of your controlled elements; electric indicators respond only to actual movement, independent of friction or sticky dampers.*

Low maintenance. *These units have no packing glands, stuffing boxes, or pilot valves. Your maintenance chores are minimized.*

Standard sizes. *Whether for 25 or for 2500 pound-feet, all torque requirements are fully met by these standard drive units.*

If your control needs would be better served by these electric drive units, why not write us about your specific applications? Address us at 4972 Stenton Avenue, Philadelphia 44, Pa.

LEEDS instruments **NORTHRUP** automatic controls • furnaces



It's happening all over the country! This time it's the West Heating Plant of G.S.A. in Washington, *D.C.* Six of the nine chutes shown above, each over 25' long by 18" O.D., are of Lukens 3/16" 20% Type 304 stainless-clad steel, purchased to assure free coal flow.

Clad Steel Chosen Again...

STAINLESS-CLAD CHUTES PROMISE FREE FLOW IN G.S.A. HEATING PLANT!

The General Services Administration is replacing worn coal chutes in its West Heating Plant with chutes of stainless-clad steel. In growing numbers, coal handling installations throughout the country are switching to clad steel equipment—because of *these demonstrated advantages:*

- substantial economies through lower maintenance costs in chutes, hoppers, bunker noses, pipes and spreaders.
- toughness proved by *installations 10 years old* which *show no measurable wear!*
- freedom from hangups and the damaging and costly effects of sulphuric acid corrosion from wet coal!
- evidence of service life that matches the life of the boiler!
- *Plus:* ready fabrication . . . the permanence of bond between stainless-clad surface and strong, low-cost carbon steel backing plate . . . over-all quality that delivers lower maintenance costs, longer life and trouble-free operation.

Want performance facts . . . product information to help your engineers make the most of clad steel . . . the names of some of the nation's best and most experienced coal handling equipment builders? Write Manager, Marketing Service, 845 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

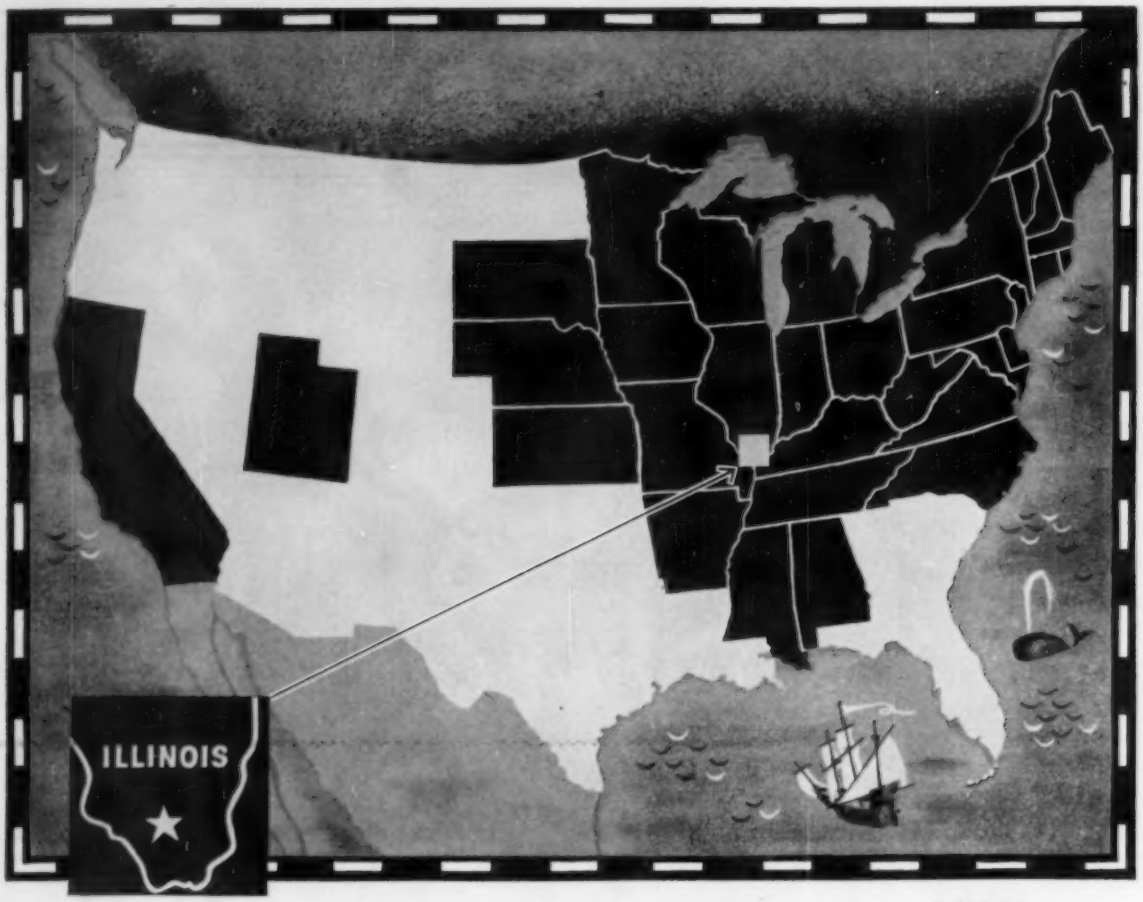
STAINLESS-CLAD STEELS

LUKENS

FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

Producers of the Widest Range of Types and Sizes of Clad Steel Available Anywhere



70 Years Young...

and serving 32 states!

From a small start in the coal fields of Southern Illinois in 1886—to distribution in 32 states from coast to coast and from Canada to the Gulf!

That's the story of Bell & Zoller's growth in service to the coal users of America; the result of our reputation and capacity for mining the consistently superior coals of the country's finest coal producing areas

... and of Bell & Zoller's proven ability to deliver these fine coals *at low cost* almost anywhere in America.

Chances are—wherever you are—that Bell & Zoller can supply the best coal for your burning equipment and power producing needs too.

Want proof? Phone your nearest Bell & Zoller office.

- Alabama
- Arkansas
- California
- Connecticut
- Delaware
- District of Columbia
- Illinois
- Indiana
- Iowa
- Kansas
- Kentucky
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota
- Mississippi
- Missouri
- Nebraska
- New Hampshire
- New Jersey
- New York
- North Carolina
- Ohio
- Pennsylvania
- Rhode Island
- South Dakota
- Tennessee
- Utah
- Vermont
- Virginia
- West Virginia
- Wisconsin

Bell & Zoller Coal Company

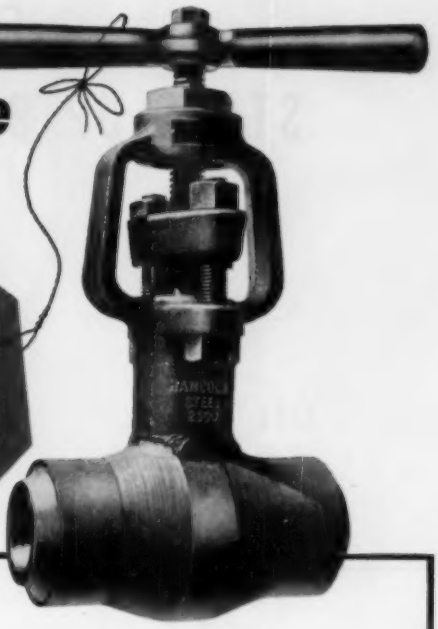
70 YEARS OF SERVICE TO COAL USERS

BELL BUILDING, CHICAGO 1, ILLINOIS

Cleveland • New York • St. Louis • Minneapolis
Omaha • Milwaukee • Louisville • Washington, D.C.
Terre Haute, Ind. • Mount Hope, W.Va.

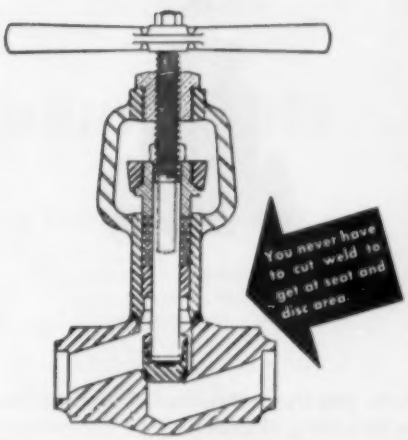
Cut valve maintenance up to 75%

Install HANCOCK 1500# and 2500# Steel Valves



• Every power plant maintenance man will agree that a lot of valuable time is lost when hours must be spent in servicing a single high pressure valve. That is why Hancock 1500# and 2500# Steel Valves are preferred for high-temperature steam lines. They rarely require attention, but when maintenance is needed, the work takes as little as one-fourth the time ordinary high pressure valves demand. Hancock Valves stay in the line for servicing. There is no danger of ruining internal parts. The bonnet weld is permanent – never has to be cut to get at the seat and disc area.

Most design and operating engineers in modern steam plants specify these high pressure Hancock Valves with maintenance requirements in mind. There is no bonnet joint to leak, no gasket to leak, no seat insert to leak! In design, in quality, in construction – in every respect – Hancock 1500# and 2500# Steel Valves have every feature essential to protect personnel, plant and service to customers. So, when you replace high pressure valves, remember that *when Hancocks go in, valve costs go down!*



SIZES: ¼" through 2". Outside screw and yoke.

SERVICE RATINGS: Screwed and socket weld ends: For all pressures up to 2500 psi at 1050° F., O.W.G. 6000 psi—100° F.

Flanged Ends: For all pressures up to 1500 psi at 900° F., O.W.G. 3600 psi—100° F.

Integral hard faced seats, hard faced discs.

CALL YOUR INDUSTRIAL SUPPLY DISTRIBUTOR for help in meeting your needs for revalving projects and new construction. You can depend on his recommendation to save you time, trouble and expense.

In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

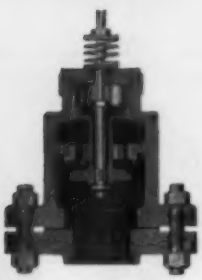
HANCOCK VALVES

A product of **MANNING, MAXWELL & MOORE, INC.** Watertown 72, Massachusetts

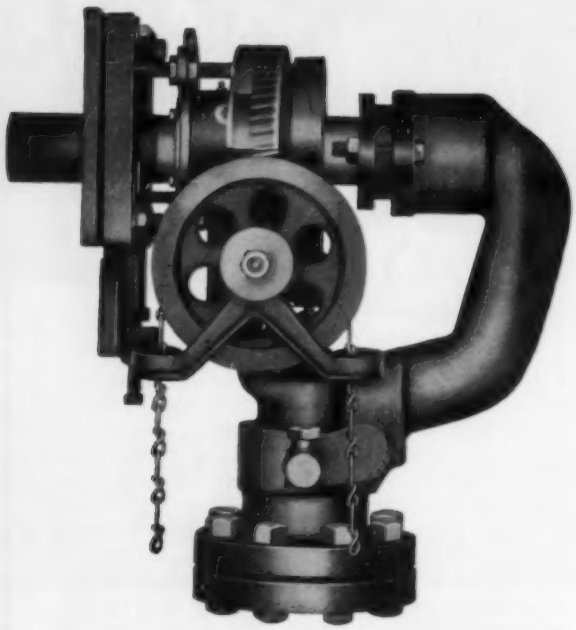
MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Oklahoma.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness



Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain *steam tight* because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

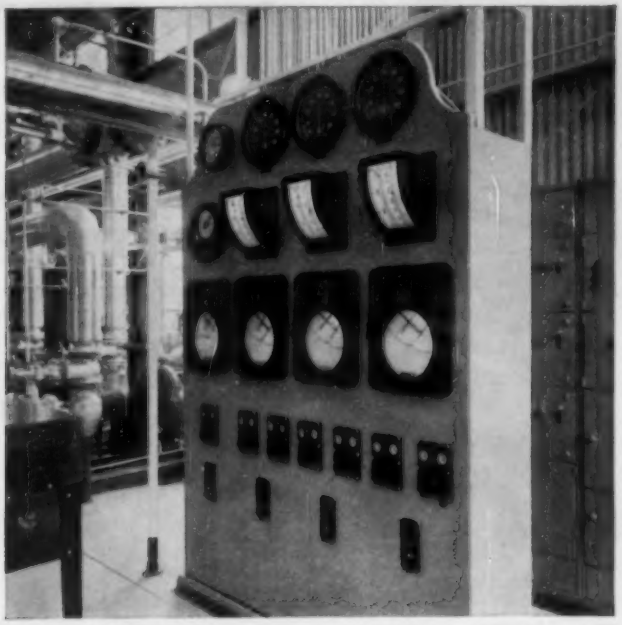
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.



Bailey Boiler Control Panel for three 150,000 lb per hr, 400 psi, gas-fired boilers. Meter at left records total Steam Flow; the other three meters record Gas Flow—Air Flow and Flue Gas Temperature.

How to Control Steam Costs

★ Close regulation of fuel and air input is vital to a strict control of your steam cost. But that's not all. You'll need control of other factors, too. Your costs can be held down only by controlling all of the important operations in your steam plant. That's where you can be sure of help from Bailey Controls. Here's why they can do the job and do it right:

1. Suitable Equipment

When you receive equipment recommendations from a Bailey Engineer his selections come from a complete line of well-engineered and carefully tested products.

2. Seasoned Engineering Experience

Your local Bailey Engineer brings you seasoned engineering experience based on thousands of successful installations involving problems in measurement, combustion, and automatic control.

3. Direct Sales-Service—close to you

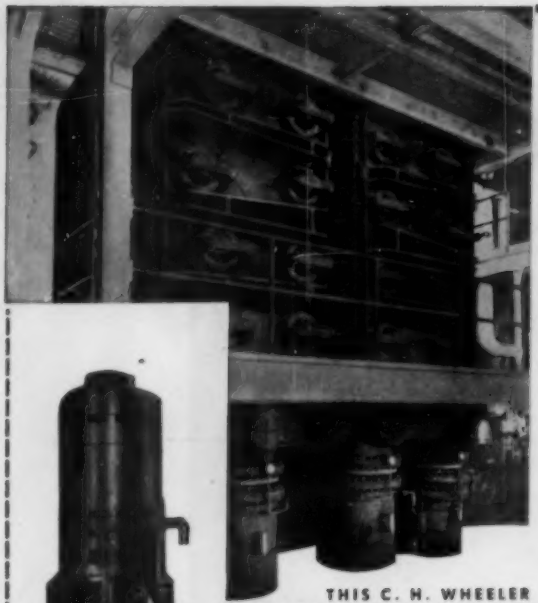
For your convenience and to save time and travel expense there's a Bailey District Office or Resident Engineer in or close to your industrial community.

For greater fuel savings, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're glad to stand on our record. A-125-1

FORMULA
for Cutting
Steam Costs
•
+ Bailey Design
+ Bailey Engineering
+ Bailey Service
= Greater Savings
per Fuel Dollar

BAILEY
METER COMPANY
1025 IVANHOE ROAD
CLEVELAND 10, OHIO
Complete Controls for Steam Plants

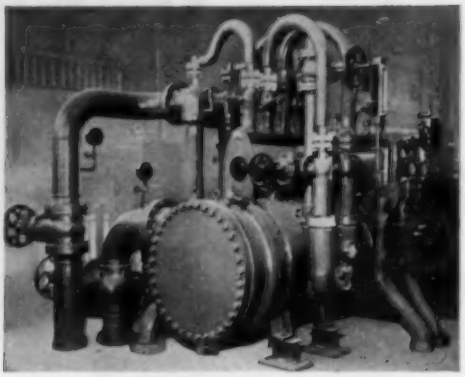
BAILEY METERS
Controls for
COMBUSTION
FEED WATER
TEMPERATURE
PRESSURE
LIQUID LEVEL
FEED PUMPS



THIS C. H. WHEELER PATENTED REVERSE FLOW SURFACE CONDENSER is a two pass, divided water box, dual bank design capable of condensing 440,000 lbs. per hour of exhaust steam. Condensing surface is 55,000 square feet.

C. H. WHEELER CIRCULATING PUMPS are 30" x 42" Vertical Mixed Flow, pull-out type. Capacity is 30,000 GPM each at a total head of 36.2 feet. Pumps are driven by 400 HP, 600 RPM synchronous speed vertical induction type motors.

"SELF-CLEANING" C. H. WHEELER PATENTED REVERSE FLOW STEAM CONDENSERS OPERATE ROUND-THE-CLOCK



C. H. WHEELER TUBEJET AIR PUMP consists of two 2-stage elements, mounted on surface type inter-after-condenser. Each 2-stage element is designed to handle 97.5 lbs. per hour air vapor mixture at 1 inch HG absolute.

New Deaerating Features Reduce Oxygen Content to Less Than 0.01 cc Per Liter

Progressive power companies are eliminating condenser shut downs and operation at reduced loads by installing C. H. Wheeler Patented Reverse Flow Steam Condensers.

One rapidly expanding utility has just put their fourth C. H. Wheeler Reverse Flow Condenser on the line. The latest unit, shown above, is not only "Self-Cleaning" but also has special new deaerating features that reduce the oxygen content of the condensate to less than 0.01 cc per liter. Continuous measurement by accurate recording instruments has proved that this low oxygen content is consistent over a wide range of load and temperature conditions.

Condenser circulating water used by this power company comes from a brackish river, laden with debris and leaves which clog steam condensers of regular design. "Self-Cleaning" C. H. Wheeler Patented Reverse Flow Condensers have solved their problem of how to avoid the expensive shut downs required to hand clean clogged tubes and tube sheets.

Debris is flushed away from the tubes and tube sheets simply by reversing the flow of cooling water through the condenser by means of hydraulically controlled built-in valves. Cleaning takes only a matter of minutes and can be accomplished under full load operating conditions with only a slight vacuum reduction. The power plant therefore can operate at full capacity round-the-clock.

Whatever your problems are . . . down time, deaeration, special operating conditions or requirements . . . let C. H. Wheeler help you solve them. Our engineering skill and experience can pay you high dividends in economy and efficiency.

Phone or write your local representative or our Philadelphia office for literature, information, or assistance.

WES07

C.H. Wheeler OF PHILADELPHIA

C. H. WHEELER MANUFACTURING CO., 19TH & LEHIGH, PHILA. 32, PENNA.

STEAM CONDENSERS · CENTRIFUGAL, AXIAL AND MIXED FLOW PUMPS · STEAM JET EJECTORS · VACUUM REFRIGERATION · HIGH VACUUM PROCESS EQUIPMENT
MARINE CONDENSERS AND EJECTORS · MARINE PUMPS · DECK MACHINERY

VERSATILITY

that does a complete coal handling job!

Coal dozer on Euclid Twin Power Scraper knocks down the pile to facilitate loading at Kansas City Power & Light.

"Twin" Scraper dumps its big load . . . spreads . . . and compacts on the fly!

The "Euc" maintains a well-drained, compacted pile . . . self loads for storage or haul to the plant.

Your coal handling costs don't have to be high! Of all the ways to stockpile and reclaim coal, none does the job as efficiently and completely as the Euclid Twin-Power Scraper.

The "Twin" is completely self-loading in loose, compacted, wet or frozen coal. It builds, raises or extends a well drained and compacted stockpile . . . carries big loads at speeds up to 30 m.p.h. Using Euclid Twin-Power Scrapers for coal handling is more economical and a great deal more flexible than permanent cranes and conveyors — from both original investment and operating standpoints. The "Twin" method costs less per ton handled — as compared to other equipment — because of the speed, capacity and versatility of these "Eucs".

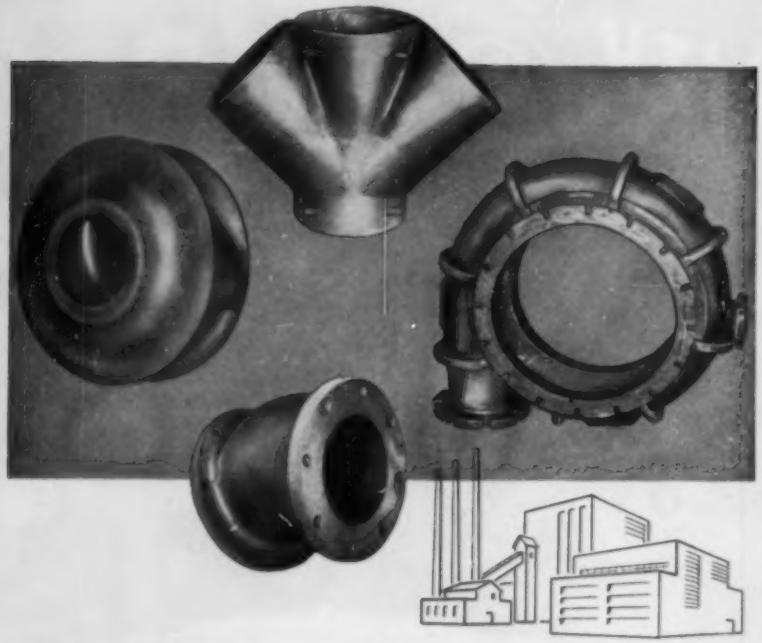
Kansas City Power & Light Co. uses a Euclid "Twin" at its big Hawthorn station and is well satisfied with the high production and low maintenance obtained. Installation of a coal dozer further increases the scraper's versatility by enabling the "Euc" to dress edges of the stockpile, knock down loose, steep piles at the delivery area, and clean up at the dumping hoppers.

Many other industrial plants and public utilities are cutting their coal handling costs with Euclid Twin-Power Scrapers. There's a good chance your Euclid Distributor can show you the way to lower costs, too!

EUCLID DIVISION GENERAL MOTORS CORPORATION, Cleveland 17, Ohio

Euclid Equipment

FOR MOVING EARTH, ROCK, COAL AND ORE



"ABRASIVE WEAR SHARPLY REDUCED" WITH ABK METAL

For longer service in pump casings, pipes, fittings and other parts subject to abrasion, install castings of ABK Metal. A nickel-chrome iron of controlled structure, ABK Metal is produced only by American Brake Shoe Co.

Time after time, on installation after installation, reports show that ABK Metal is the most economical material for handling ash. The ultimate saving on replacement parts alone is appreciable. The saving in maintenance and shut-downs may be even higher.

Extended life of 4 or 5 to 1 is not unusual when ABK Metal replaces other iron castings—especially in those ash handling or disposal systems where the most severe type of abrasion is encountered. Don't let ABRASION steal your operating dollars . . . SPECIFY ABK METAL.

ABK METAL fights ABRASION

1533 American Brake Shoe COMPANY

BRAKE SHOE AND CASTINGS DIVISION
230 Park Avenue, New York 17, N. Y.

Advertisers' Index

Aerotec Corporation, The.... *
Air Preheater Corporation, The 2
Allis-Chalmers Mfg. Company, Construction Machinery Div. 73
Allis-Chalmers Mfg. Company, General Machinery Div..... *
American Blower Corporation .....6 and 7
American Brake Shoe Company..... 82

Bailey Meter Company..... 79
Baltimore & Ohio Railroad.... 14
Barber-Colman Company, Wheelco Instruments Div.... *
C. O. Bartlett & Snow Company, The..... 71
Bayer Company, The..... 78
Bell & Zoller Coal Company... 76
Blaw-Knox Company, Blaw-Knox Equipment Div..... *
Buell Engineering Company, Inc..... 8
Buffalo Forge Company..10 and 11

Carborundum Company, The. *
Chain Belt Company..... *
Chesapeake & Ohio Railway... 28
Clarage Fan Company..... 84
Cochrane Corporation..... 31
Coen Company..... *
Combustion Engineering, Inc. ....Second Cover, 16 and 17
Combustion Publishing Company, Inc..... *
Copes-Vulcan Div., Blaw-Knox Company.....20 and 21
Crane Company..... *

Dampney Company, The..... 67
Dearborn Chemical Company. 29
De Laval Steam Turbine Company..... 70
Diamond Power Specialty Corporation.....Third Cover
Dowell Incorporated..... 25

Eastern Gas & Fuel Associates. *
Economy Pumps, Inc..... 80
Edward Valves, Inc..... *
Enos Coal Mining Company, The..... 63
Ernst Water Column & Gage Company.....66 and 68
Euclid Division, General Motors Corporation..... 81

Fairmont Coal Bureau..... 64
Flexitallic Gasket Company... *
Foster Engineering Company.. *

General Electric Company..... *
General Refractories Company 13
Gifford-Wood Company..... 30
Graver Water Conditioning Company..... *
Green Fuel Economizer Company, Inc..... *
Grinnell Company, Inc..... *

(Continued on page 83)

Hagan Corporation..... 4
Hall Laboratories, Inc..... 4
Haskins-Turner Co..... 60

Ingersoll-Rand Company..... 22

Johns-Manville..... 3

M. W. Kellogg Company..... 24
Koppers Company, The..... 19

L. A. Water Softener Co..... 62
Leeds & Northrup Company... 74
Lukens Steel Company..... 75
Lummus Company, The..... *

Madden Corporation, The..... 56
Manning, Maxwell & Moore, Inc..... 77
W. K. Mitchell & Company.... 5

National Aluminate Corporation..... 26
National Coal Association..... 27
Norfolk and Western Railway.. *

Olin Mathieson Chemical Corporation..... *

Peabody Engineering Corporation..... *
Pipe Fabrication Institute, The 23
Pittsburgh Piping & Equipment Company..... *
Poole Foundry & Machine Company..... 60
Powell Valves..... 72
Prat-Daniel Corporation..... 68

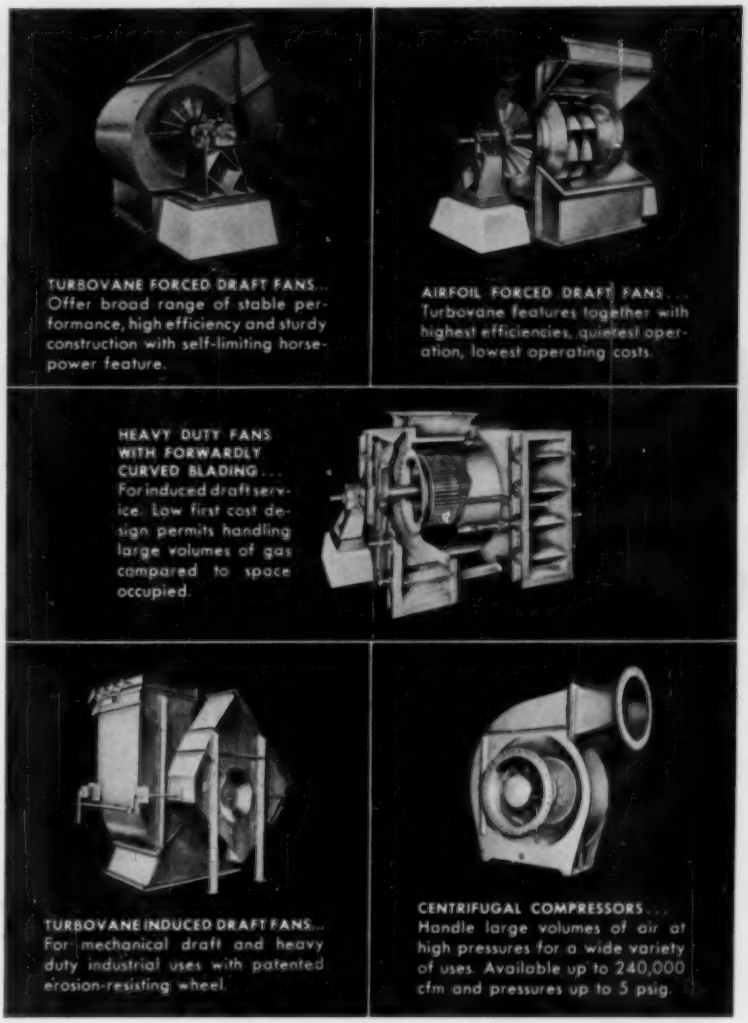
Refractory & Insulation Corporation..... 63
Reliance Gauge Column Company, The..... 65
Republic Flow Meters Company..... 12
Republic Steel Corporation.... *
Research-Cottrell, Inc..... *
Richardson Scale Company.... 69

Benjamin F. Shaw Company.. 32
Stock Equipment Company... 15
Sy-Co Corporation..... *

W. A. Taylor and Co..... *
Thermix Corporation..... *
Todd Shipyards Corp., Products Division..... *

Walworth Company..... 18
Western Precipitation Corporation.....Fourth Cover
Westinghouse Electric Corporation, Sturtevant Div..... 83
C. H. Wheeler Manufacturing Company..... 80

Yarnall-Waring Company.... 9


TURBOVANE FORCED DRAFT FANS... Offer broad range of stable performance, high efficiency and sturdy construction with self-limiting horsepower feature.
AIRFOIL FORCED DRAFT FANS... Turbovane features together with highest efficiencies, quietest operation, lowest operating costs.
HEAVY DUTY FANS WITH FORWARDLY CURVED BLADING... For induced draft service. Low first cost design permits handling large volumes of gas compared to space occupied.
TURBOVANE INDUCED DRAFT FANS... For mechanical draft and heavy duty industrial uses with patented erosion-resisting wheel.
CENTRIFUGAL COMPRESSORS... Handle large volumes of air at high pressures for a wide variety of uses. Available up to 240,000 cfm and pressures up to 5 psig.

A Complete Line of Forced and Induced Draft Fans for Utility and Industrial Power Generation

These and many other designs available for:

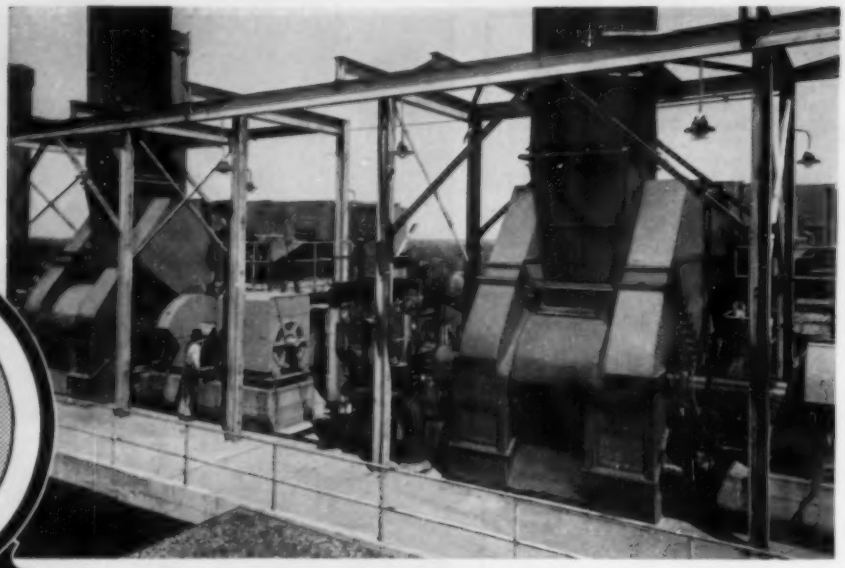
- ★ **primary and secondary forced draft**
- ★ **induced draft**
- ★ **gas recirculation**

Complete engineering application service by Westinghouse-Sturtevant is available to you to solve any mechanical draft problem. Call our Sales Engineer, or write Westinghouse Electric Corporation, Sturtevant Division, Dept. 2C, Hyde Park, Boston 36, Mass.

WESTINGHOUSE AIR HANDLING

YOU CAN BE SURE...IF IT'S Westinghouse

J-80453



MARATHON

chooses marathon performers in the mechanical draft field

Clarage Fans Installed at Ohio Oil's Refinery, Robinson, Ill.

"Best in the long run" is Marathon's slogan for its gasoline. But there's growing opinion that these five words aptly describe Clarage equipment as well.

For example, Ohio Oil's $3,500,000 improvement and expansion program for their power plant required the removal of Clarage induced draft fans which had been on the job continuously since 1926. Think of it, nearly 30 years of service under the most punishing conditions a fan can encounter. Value received — in full!

Small wonder that two Clarage Type RT induced draft fans and two Clarage Type W forced draft fans were selected to serve the two 180,000 lbs. per hour Riley boilers in the modernized plant.

These fans are installed outdoors on an elevated platform, and are equipped with dual drives arranged for automatic control on both the turbine drive and the motor drive. The turbine is kept hot at all times so that it will start operating automatically in the event of failure of the motor, magnetic coupling, or electrical system.

If, like The Ohio Oil Company, you want marathon performers in the mechanical draft field, by all means investigate the equipment we offer. CLARAGE FAN COMPANY, Kalamazoo, Michigan.

CLARAGE ... *dependable equipment for making air your servant*

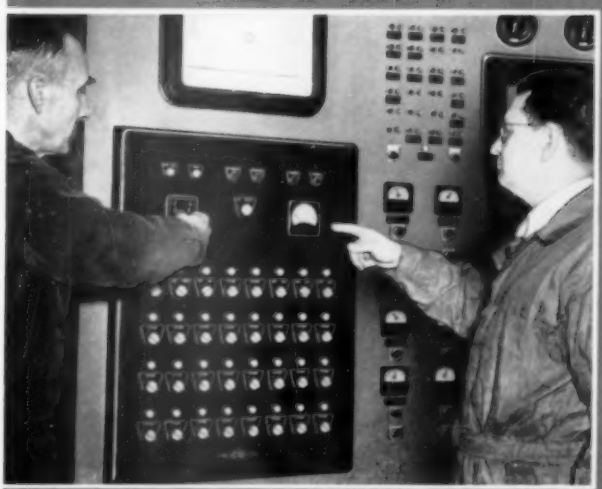
SALES ENGINEERING OFFICES IN ALL PRINCIPAL CITIES • IN CANADA: Canada Fans, Ltd., 4285 Richelieu St., Montreal

DIAMOND SERVICE POLICY

Improves

BOILER CLEANING AND SAVES YOU MONEY

Diamond Service Engineer needs only a screwdriver to change the steam blowing pressure of an individual G9B Blower after his inspection of tube surfaces indicated that a pressure increase will improve cleaning in that particular location.



Diamond Service Engineer instructs operator in use of the Diamond Selectro-matic Control Panel . . . how simple it is to change from single blower selection to a completely automatic sequential program.

The severe punishment that boiler cleaning equipment must take in the normal course of its operation emphasizes the importance of the unique Diamond Service Policy. Throughout the 36 years it has been in force, this Diamond Service Policy has made significant savings and important improvements in boiler cleaning for many users of Diamond Blowers.

Every installation of Diamond Blowers in stationary water tube boilers is regularly inspected and adjusted *(unsolicited and without charge)* by one of the many full-time Diamond Field Service Engineers working from strategic points throughout the country. On an inspection call, the Diamond Service Engineer sees to it that the blowers are in good repair and adjustment . . . instructs operators in their correct use and care . . . recommends blowing schedules for maximum economy. Often he will detect potential trouble before it becomes serious or costly. This preventive maintenance has been of great value to many operators.

Numerous users tell us that this unique Diamond Service Policy was as important as the superior design of Diamond Blowers in their decision to buy Diamond equipment.

DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

Diamond Specialty Limited • Windsor, Ontario

For the Maximum in Fly Ash Recovery...

... an unbiased recommendation from

WESTERN PRECIPITATION

The only organization with 48 years of dust collection experience.

ELECTRICAL, MECHANICAL and CMP *types of recovery systems.*

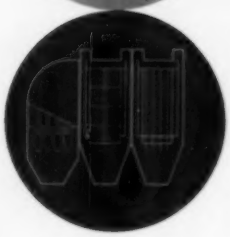
COTTRELL *Electrical* PRECIPITATORS

Western Precipitation pioneered commercial application of the now-famous Cottrell **Electrical** Precipitator—has more know-how, more experience, more basic advancements in this highly-technical electrostatic field of recovery than any other organization, domestic or foreign.

MULTICLONE *Mechanical* COLLECTORS

Western Precipitation pioneered the multiple small tube type of cyclonic collector—the type with higher centrifugal forces for greater recovery efficiencies. Multiclones are also easier to install, service and maintain—and require less space than other equipment of comparable capacity.

CMP *Combination* SYSTEMS!



Western Precipitation pioneered the CMP (**C**ombination **M**ulticlone-**P**recipitator) type of recovery unit now favored by so many leading power plant operators—the unit that combines advantages of both the Mechanical and Electrical principles, and provides almost constant collection efficiency despite varying gas volume.

Plus **invaluable know-how**

The most important part of **every** Western Precipitation installation is this organization's unequalled experience gained through almost a half-century of continuous leadership in the highly-complex science of recovering suspensions from industrial gases. No other organization—anywhere—offers such seasoned judgment in Electrical, Mechanical and CMP recovery methods. Yet you pay nothing extra for this invaluable "know-how"!

Let us send you literature which describes Western Precipitation's unique services in greater detail. Write, wire or phone our office nearest you!

WP

COTTRELL Electrical Precipitators
MULTICLONE Mechanical Collectors
CMP Combination Units
DUALAIRE Reverse-Jet Filters
HOLO-FLITE Processors

Western Precipitation Corporation

Designers and Manufacturers of Equipment for Collection of Suspended Materials from Gases and Liquids

Main Offices: **1022 WEST NINTH STREET, LOS ANGELES 15, CALIFORNIA**

Chrysler Bldg., New York 17 • 1 North La Salle Street Bldg., Chicago 2 • Oliver Bldg., Pittsburgh 22 • 3252 Peachtree Rd. N. E., Atlanta 5 • Hobart Bldg., San Francisco 4 • Precipitation Co. of Canada Ltd., Dominion Sq. Bldg., Montreal